Gypsy Moth Management in the United States:
a cooperative approach

Final

Environmental Impact Statement

Volume II of V
Chapters 1-9 and Appendixes A-E

November 1995

United States Department of Agriculture

Forest Service

Animal and Plant Health Inspection Service

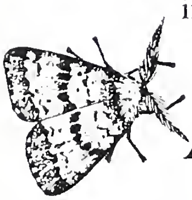
Han[illegible] and

Strate[illegible]

suppression- [illegible] areas where the insect is [illegible]

eradication- [illegible] vent establishment in new areas

slow the spread—keeping low level populations of the gypsy moth from rapidly increasing, to slow the spread of the insect from areas where it is already established



Alternatives

Alternative 1—No suppression, no eradication, no slow the spread
Alternative 2—Suppression
Alternative 3—Eradication
Alternative 4—Suppression and eradication
Alternative 5—Eradication and slow the spread
Alternative 6—Suppression, eradication, and slow the spread

The complete final environmental impact statement, Gypsy Moth Management in the United States: a cooperative approach, consists of five volumes:

Volume I. Summary
Volume II. Chapters 1-9 and Appendixes A-E
Volume III. Appendix F, Human Health Risk Assessment
Volume IV. Appendix G, Ecological Risk Assessment
Volume V. Appendix H, Comments on the Draft Environmental Impact Statement, and Responses

The record of decision is a separate document published and available 30 days or longer after the notice of availability for the final environmental impact statement is published in the Federal Register (40 CFR Part 1506.10).

Acknowledgment: *Photographs on the first page of chapters and appendixes were taken from* The Gypsy Moth *by Edward H. Forbush and Charles H. Fernald, which was published in 1896 by Wright and Potter Printing Co., Boston.*

Gypsy Moth Management in the United States: a cooperative approach

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Abstract: To protect the forests and trees of the United States from the adverse effects of the gypsy moth, two USDA agencies—the Forest Service and the Animal and Plant Health Inspection Service (APHIS)—propose to adopt a new national gypsy moth management program. This program will allow these agencies to cooperate with States and other Federal agencies in gypsy moth projects. This cooperation could include providing assistance to suppress potentially damaging gypsy moth populations in areas where the insect is established, to eradicate gypsy moth introductions, and to slow the gypsy moth's spread from the area where the insect is already established. Six alternatives are proposed: 1—no suppression, no eradication, no slow the spread; 2—suppression; 3—eradication; 4—no change from the existing program of suppression and eradication; 5—eradication and slow the spread; 6—suppression, eradication, and slow the spread (preferred alternative). Before treatments would be conducted on Federal, State, or private land, site-specific environmental analyses would be carried out for each planned project, in accordance with the National Environmental Policy Act and agency regulations.

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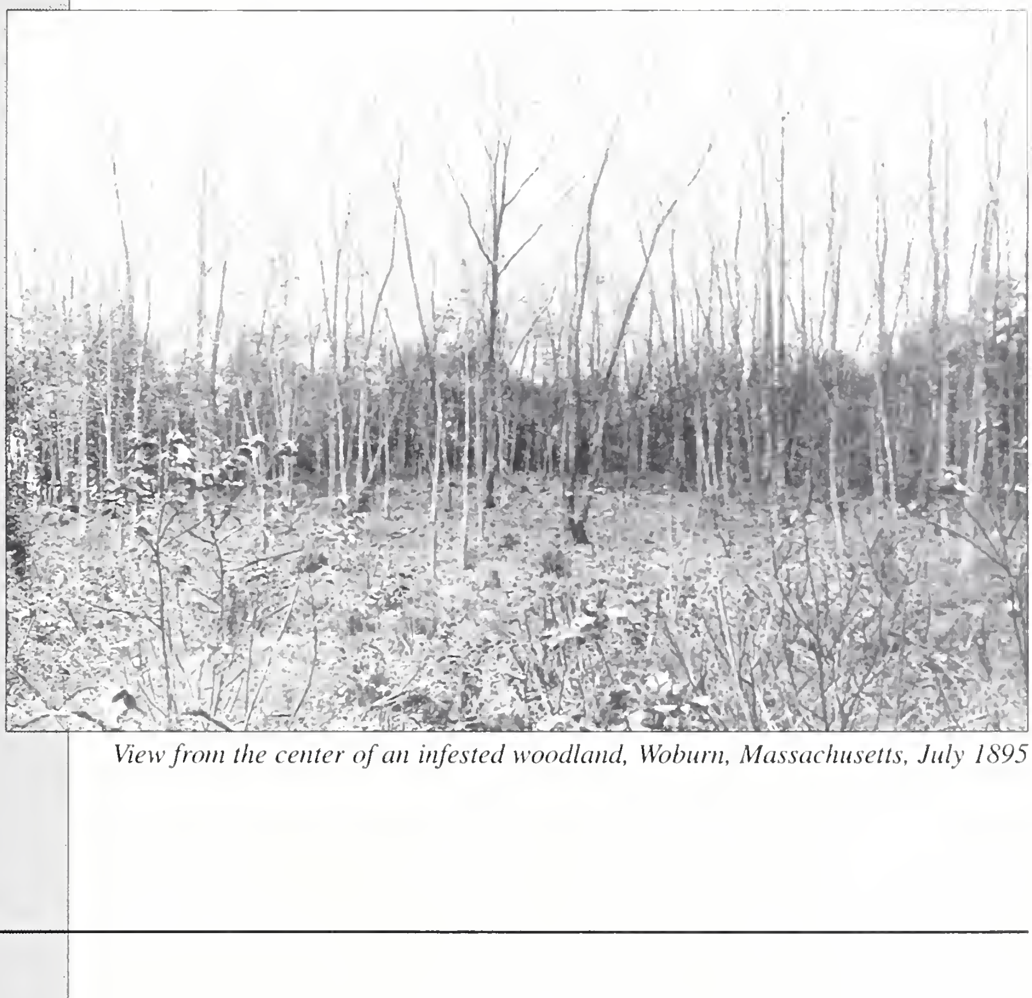


View from the center of an infested woodland, Woburn, Massachusetts, July 1895

Chapter 1
Purpose of and Need for Action

Contents

The U.S. Department of Agriculture (USDA) is responsible for activities related to the gypsy moth (*Lymantria dispar* [L.]) at the Federal level. The goal of the department's gypsy moth program is to reduce the adverse effects of the gypsy moth nationwide. A departmental regulation assigns responsibilities to several USDA agencies, including the Forest Service and the Animal and Plant Health Inspection Service (APHIS), and establishes the following gypsy moth policy (USDA 1990a):

- Provide a comprehensive program of gypsy moth management activities
- Protect Federal lands and assist States in protecting non-Federal lands from gypsy moth damage
- Prevent or reduce the artificial spread of the gypsy moth by people
- Develop effective gypsy moth eradication or suppression programs
- In cooperation with the States, conduct uniform gypsy moth surveys and evaluations.

In keeping with USDA policy, the Forest Service and APHIS are proposing to adopt a new national gypsy moth management program.

In 1985, the Forest Service and APHIS prepared an environmental impact statement that proposed four alternatives for suppressing or eradicating gypsy moth infestations (USDA 1985). The alternative selected was implementing integrated pest management (IPM), which involves selecting strategies to manage pest-host systems for specific purposes. IPM includes planning, detection, evaluation, monitoring, defining acceptable damage, and using appropriate management practices to prevent or control pest-caused damage and losses. The USDA has carried out its gypsy moth responsibilities under that environmental impact statement since 1985.

Several changes in gypsy moth status and management techniques have occurred since the Forest Service and APHIS published the 1985 environmental impact statement:

- The introduction of the Asian strain of the gypsy moth from Russia and Germany.
- A trend away from use of the broad spectrum chemical insecticides acephate, carbaryl, and trichlorfon, to insecticides that are more specific to the gypsy moth and more acceptable to the public.
- The development of new information on gypsy moth management including noninsecticidal treatments like mating disruption to manage low level populations.
- The development and pilot-testing of a new management strategy to slow the spread of the gypsy moth.

The importance of these changes indicated that a new programmatic environmental impact statement on the gypsy moth was needed.

This environmental impact statement presents a range of program alternatives that could be adopted and examines the potential consequences of implementing them.

Organization of This Document

This chapter tells why the gypsy moth is considered to be a problem and what the USDA proposes to do about it. The chapter identifies the principal issues concerning the gypsy moth and treating it. For those not familiar with the gypsy moth, this chapter gives information on its life cycle, differences between the European and Asian strains, population outbreaks, and plants that the caterpillars eat. *Chapter 1* forms an executive summary with *chapter 2*, which describes and compares the proposed alternatives.

Chapter 3 describes the environment that could be affected by the gypsy moth and treatments, and *chapter 4* tells what the effects could be.

Chapter 4 (Environmental Consequences) is divided into three parts: Effects on Human Health and Safety, Ecological Effects, and Consequences of the Alternatives. Because this document is national in

scope, the consequences of the alternatives are broad. Detailed information on human health and ecological effects is provided to aid in conducting site-specific environmental analyses and for incorporation by reference into any site-specific environmental documents (40 CFR 1502.21).

Chapter 5 lists the preparers of this document, *chapter 6* lists the Consultants and Contributors who provided information, and *chapter 7* lists those who were mailed a copy of this final environmental impact statement.

Chapter 8 (Glossary) defines terms used, and *chapter 9* lists references cited in volume II.

Appendixes A through *E* cover Gypsy Moth Treatments, the Gypsy Moth Program, Public Involvement and Issues, Plant List, and History of the Gypsy Moth and Control Efforts.

Appendix F (Human Health Risk Assessment), *appendix G* (Ecological Risk Assessment), *appendix H* (Comments on the Draft Environmental Impact Statement, and Responses), and the Summary of this environmental impact statement are each bound separately.

Need for Action

The gypsy moth is a nonnative insect that was brought to the United States from Europe and accidentally released in eastern Massachusetts in the late 1860's. Despite many early attempts to halt its spread, by 1994 the gypsy moth had become established in all or parts of 16 States plus the District of Columbia: Connecticut, Delaware, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, and West Virginia. It continues to spread into uninfested areas.

The gypsy moth caterpillar alters ecosystems and disrupts people's lives when it feeds heavily on the foliage of trees, shrubs, and other plants. Heavy feeding causes defoliation, which weakens trees and increases their vulnerability to other insects and diseases that may kill them; alters wildlife habitat; changes water quality; reduces property values and the esthetic value of public and private woodlands; and reduces the recreation value of forested areas.

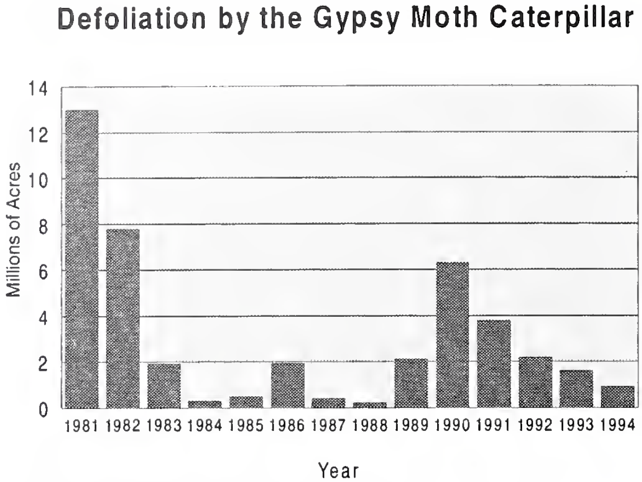


Figure 1-1. Acres defoliated by the gypsy moth caterpillar in the United States varied widely from 1981 to 1994.

When present in large numbers, gypsy moth caterpillars can be a nuisance, as well as a hazard to health and safety. Effects due to the gypsy moth are described in *chapter 4*.

At risk from defoliation by the gypsy moth are at least 311 million acres (126 million ha) of areas classified as forest lands in the United States that are dominated by trees susceptible to gypsy moth feeding (Powell and others 1993). Also at risk are countless urban and rural forested areas throughout the country where susceptible plants grow naturally or have been planted. Past defoliation by the gypsy moth is shown in *figure 1-1*.

In 1991, an Asian strain of the gypsy moth was found for the first time in Oregon and Washington, and in British Columbia, Canada. Eradication projects conducted in 1992 and 1993 appear to have successfully eliminated the insect from those areas. The introduction was traced to ships arriving from ports in the Russian Far East. The Asian strain poses a greater risk of rapid spread. Unlike females of the European strain, females of the Asian strain may fly and deposit an egg mass miles from where they fed as caterpillars. The Asian strain also poses a greater risk of damage because it feeds on a greater variety of plants. The Asian strain was also introduced into North Carolina in 1993 on military cargo returning from Germany, and an eradication project was conducted in southeastern North Carolina in 1994 and 1995.

Purpose of Action

The purpose of the proposed action is to protect the forests and trees of the United States from the adverse effects of the gypsy moth.

Heavy gypsy moth feeding causes defoliation.

Proposed Action

The Forest Service and APHIS propose to adopt a new national gypsy moth management program that follows an IPM approach. The program allows for treatment to suppress potentially damaging gypsy moth populations in the areas where it is already established (suppression), to eliminate isolated infestations of the gypsy moth from areas where it is not already established (eradication), and to slow the gypsy moth's spread from areas where it is already established, by keeping low level populations from building (slow the spread) (*fig. 1-2*).

Treatments available for use in suppression projects include the insecticides *Bacillus thuringiensis* var. *kurstaki*, diflubenzuron, and the gypsy moth nucleopolyhedrosis virus product (Gypchek). Treatments available for use in eradication or slow-the-spread projects include these insecticides plus noninsecticidal methods of mass trapping, mating disruption, and the sterile insect technique. Effectiveness and use of these treatments, as well as a description of other treatments that were considered, are given in *appendix A* on Gypsy Moth Treatments.

The decision resulting from this environmental impact statement could enable the Forest Service and APHIS to conduct gypsy moth treatment projects. The decision could identify the conditions and the kinds of treatments for which assistance will be provided to State and Federal agencies.

The Forest Service, APHIS, other Federal agencies, and State agencies with gypsy moth management responsibilities conduct annual surveys to identify areas with the potential for gypsy moth defoliation. These surveys include population surveys in the generally infested area and detection surveys outside the generally infested area. Agencies that identify a need for gypsy moth treatment and USDA assistance prepare proposals for treatment projects that may include requests for cost-sharing.

Federal agencies that request USDA assistance for gypsy moth projects are subject to the requirements of the National Environmental Policy Act (42 U.S.C. section 102), which requires that environmental analyses be conducted before action can be taken. For projects on non-Federal lands, environmental analyses are conducted by the States in cooperation with the Forest Service or APHIS. For projects on Federal lands, environmental analyses are prepared by the requesting Federal agency in compliance with their policy on implementing the National Environmental Policy Act.

The Forest Service conducts gypsy moth treatment projects on National Forest System lands. Other gypsy moth projects are conducted by the Forest Service and APHIS or by the requesting Federal or State agency.

Proposed treatment projects will be analyzed on an individual basis to determine if they are biologically sound, environmentally acceptable, and economically efficient. Suppression projects are often found to be economically efficient depending on the resource manager's or landowner's objectives and the

Infestation status, 1994

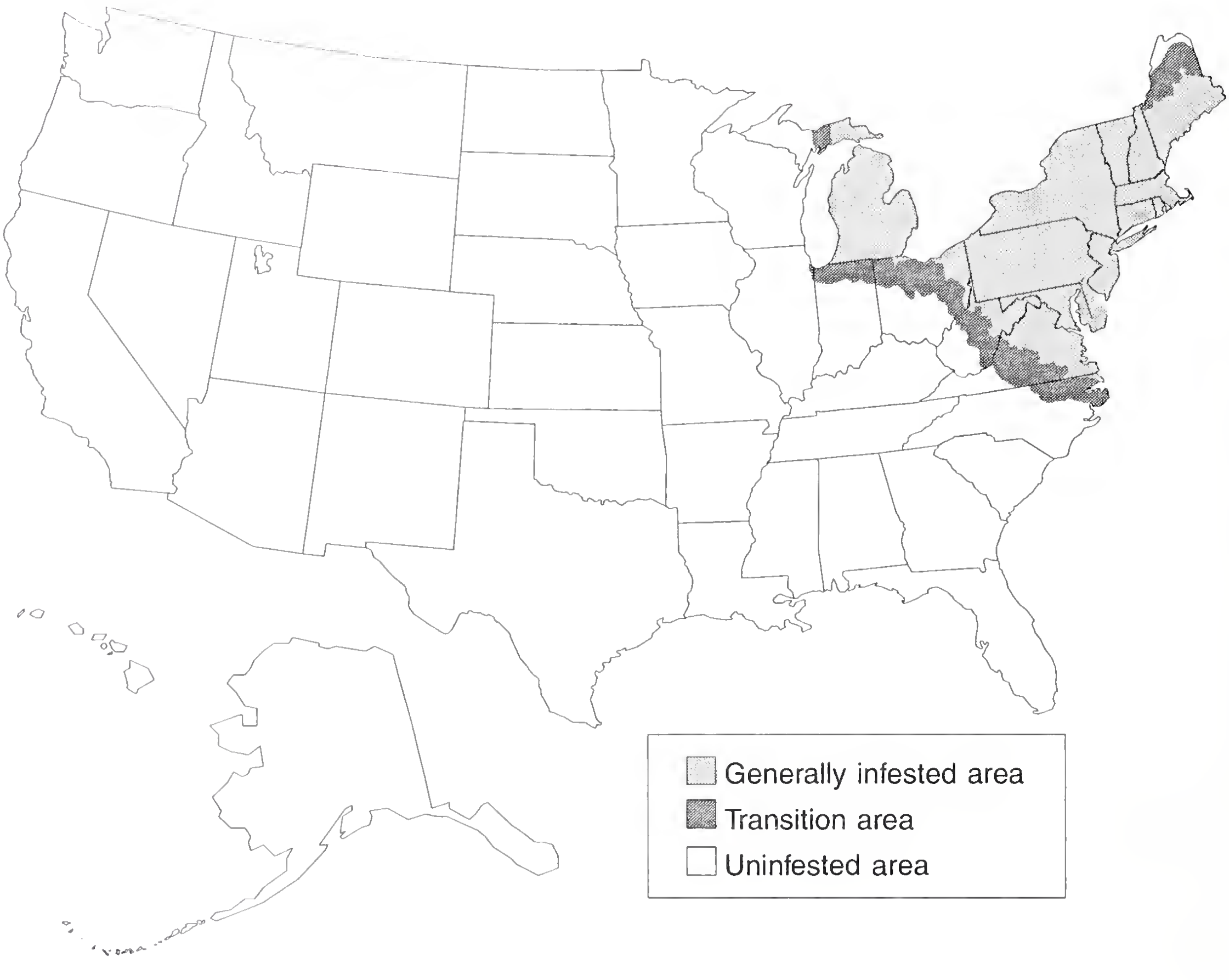


Figure 1-2. The three strategies for the gypsy moth would be implemented in different parts of the country: suppression in the generally infested area, eradication in the uninfested area, and slow the spread in the transition area. The Asian strain of the gypsy moth would be eradicated wherever it is found, including the generally infested area when the source of the introduction is known.

values at risk. Benefits of suppression include avoidance of tree loss that would affect recreational, residential, watershed, wildlife, or timber values. The greatest economic benefit of eradication is the avoidance of long-term suppression costs. Economic analysis indicates the potential for high economic efficiency from slow the spread (Leuschner 1991).

Scope of This Document

This environmental impact statement examines six broad programmatic alternatives that the Forest Service and APHIS could adopt to manage gypsy moth populations in the United States. Other gypsy-moth-related activities, such as treatment of quarantined items infested with gypsy moths, the

boarding and inspection of ships entering U.S. seaports, and research and methods development activities, are outside the scope of this document and are not examined. (For a description of all the activities in USDA's gypsy moth program, see *appendix B*.)

This environmental impact statement provides guidance for only those situations in which the USDA conducts a gypsy moth project or is asked by a cooperator to participate in a gypsy moth project. Actions of other Federal, State or local agencies, or of private citizens to manage the gypsy moth on their own are not constrained by this environmental impact statement, but only by applicable Federal and State laws, local ordinances, insecticide label instructions, and any self-imposed constraints.

The information and analysis contained in this environmental impact statement can be incorporated by reference into environmental documents prepared for proposed treatment projects, in accordance with the National Environmental Policy Act and agency regulations.

Issues

The interdisciplinary team who prepared this environmental impact statement (listed in *chapter 5*) was joined by public affairs specialists and forest pest managers throughout the Forest Service and APHIS (listed in *chapter 6*), to involve the public and to ensure that this environmental impact statement serves all areas of the United States. A public affairs plan was implemented to determine the scope of issues relating to the gypsy moth and gypsy moth treatments.

On November 12, 1992, a notice was published in the *Federal Register* describing the intent of the Forest Service and APHIS to prepare an environmental impact statement. The notice opened a formal 120-day period for the public to provide input (USDA Forest Service 1992).

News items were released to national and regional press, and information was distributed within the Forest Service and APHIS. Nearly 23,000 letters were mailed to individuals and organizations that might have an interest in the gypsy moth and gypsy moth treatments. These included Federal, State, and local officials; American Indian tribes; scientists; members of conservation and environmental groups; people in forestry, nursery, and related industries; homeowners and landowners in gypsy moth infested areas; people who are physically sensitive to insecticides; and people interested in forest recreation.

The preparers also attended meetings and provided presentations to Forest Service and APHIS managers nationwide and to groups outside the agencies, to solicit comments. Articles appeared in several Forest Service and APHIS publications, and in one trade journal (American Nurseryman 1993).

In response to these efforts to gather input on the scope of the issues, 827 letters were received during the formal comment period. Additional comments were received both before and after this period.

Letters with questions and information requests were answered individually.

An analysis of the comment letters identified over 3500 substantive comments. Two hundred concerns emerged that were grouped in broad categories for further discussion and planning. These concerns were addressed by using them to define the principal issues, the alternatives, and environmental and human factors that were analyzed. For more information on scoping and public involvement, and on how the public comments were used, see *appendix C* on Public Involvement and Issues.

Changes in gypsy moth status and management techniques indicate the need for a new environmental impact statement.

Purpose

Three principal issues are addressed in this environmental impact statement:

1. How does the presence of the gypsy moth affect people and the environment?
2. How do the insecticide treatments applied to the gypsy moth affect people and the environment?
3. How do the noninsecticidal treatments applied to the gypsy moth affect people and the environment?

The three issues encompass the following topics, which were examined for effects due to the gypsy moth and treatments: human health and safety, perceptions and behaviors, economics, recreation, kinds and numbers of nontarget organisms, forest condition, water quality, microclimate, and soil productivity and fertility. The resulting information was used to analyze the consequences of the alternatives (*chapter 4*).

Heavy defoliation can alter ecosystems.

Statutory Authorities

Under broad discretionary authority given by several Federal laws, agencies of the USDA conduct the following pest management activities:

- Prohibiting the importation of nursery stock into the United States without permit; and quarantining States, Territories, and the District of Columbia to prevent the spread of plant pests and diseases new to or not widely prevalent in the United States (The Plant Quarantine Act of 1912, as amended [7 U.S.C. sections 151-165, 167]).
- Prohibiting the movement of plant pests from a foreign country into or through the United States, or between States, without a permit; and declaring emergencies to prevent the dissemination of plant pests new to or not widely prevalent in the United States (The Federal Plant Pest Act of 1957, as amended [7 U.S.C. sections 150aa-150jj]).
- Acting alone or in cooperation with the States and others, to detect, eradicate, suppress, control, or to prevent or retard the spread of plant pests (The Department of Agriculture Organic Act of 1944, as amended [7 U.S.C. section 147a]).
- Entering into cooperative agreements with States to avoid duplication of functions, facilities, and personnel; and attaining closer coordination and greater effectiveness in administering Federal and State laws and regulations to control or eradicate plant pests (Cooperation with State Agencies in Administration and Enforcement of Certain Federal Laws [7 U.S.C. section 450]).
- Cooperating with Federal agencies and States to manage forest insects and diseases; the Secretary of Agriculture is authorized to assist in controlling forest insects and diseases directly on National Forest System land and in cooperation on other Federal and non-Federal lands of all ownerships (The Cooperative Forestry Assistance Act of 1978 [16 U.S.C. section 2101 (note)], as amended by the Forest Stewardship Act of 1990 [16 U.S.C. section 2101 (note)]).

Many laws and authorities influence how actions to manage pests, including the gypsy moth, are implemented at the local level, such as the the Wilderness Act (16 U.S.C. section 1131 [note]), the Endangered Species Act of 1973 (16 U.S.C. sections 1531-1536, 1538-1540), and the National Forest Management Act of 1976 (16 U.S.C. section 1600 [note]). State and Federal agencies will determine which laws and authorities are applicable to the proposed projects and consider them when conducting environmental analyses.

Information About the Gypsy Moth

This information about the gypsy moth is provided for better understanding of the insect, the problems it creates, and treatments applied to it.

Life Cycle of the Gypsy Moth

The gypsy moth has one generation per year and goes through four life stages: larva (caterpillar), pupa, adult (moth), and egg (*fig. 1-3*). Only the caterpillar feeds on leaves, causing damage to trees and shrubs.

Eggs laid the previous year hatch in spring (April and May in the Middle Atlantic States), and caterpillars climb up trees or other objects and spin a thread of silk which hangs freely from the trees. Before caterpillars begin feeding, most crawl down on the silk thread and are carried to new locations by the wind—a phenomenon termed ballooning. Caterpillars may balloon several times before they settle and begin feeding on foliage (Nichols 1980).

Caterpillars grow from one-tenth of an inch (3 mm) to as large as $3^1/_2$ inches (90 mm) by repeatedly shedding their skin (molting). Instars are the stages between molts. Male caterpillars grow through five instars and females through six, although an additional instar is not uncommon (Doane and McManus 1981). Caterpillars continue to feed and grow for about 8 weeks. During this period of feeding gypsy moth caterpillars may cause defoliation. The feeding caterpillar is the life stage targeted in most gypsy moth treatment projects.

When population levels are low, caterpillars move down the tree and rest during the day in protected areas, such as under the tree bark or in crevices, and return to the tree canopy to feed at night. When populations are high, however, caterpillars remain in the tree canopy and feed night and day. When the foliage of the host tree is stripped, the caterpillars crawl in search of new sources of food (McManus and others 1989).

At the end of the last instar (June and July in the Middle Atlantic States) caterpillars crawl to protected spots in trees, on buildings, and on the ground, and change to pupae over a period of about 2 days. The pupal stage lasts about 2 weeks, and at the end of it adult moths emerge.

Males appear several days earlier than females do. When the egg-laden female moths emerge, they emit a pheromone—a chemical that attracts males for mating. After mating, the female deposits eggs in a well-defined mass that may contain from a few hundred to almost a thousand eggs. She coats the eggs with hairs from her abdomen, giving the egg mass a furry appearance and buff color. Eggs are usually laid in protected areas, such as in bark crevices, on the underside of branches, and in leaf litter. Adult moths do not feed; they die shortly after mating and egg laying.

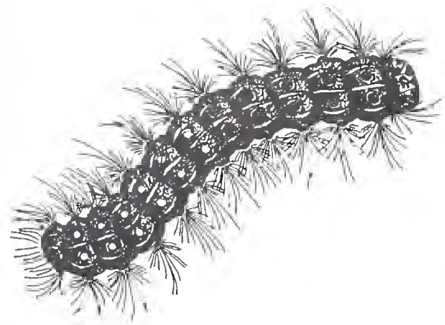
The embryos develop into caterpillars within the eggs in 4 to 6 weeks, and the caterpillars remain in the eggs during winter. Survival and hatching success depend on a combination of time and temperature requirements. A prolonged period of chilling and subsequent incubation are necessary for egg hatch the next spring (Giese and Casagrande 1981).

European and Asian Strains

The European strain of the gypsy moth became established in North America from a single introduction of closely related individuals, and genetic studies have shown little variation within or between populations (Wallner 1992). In North America the European strain is also called the North American strain. What is commonly referred to as the Asian strain of the gypsy moth is actually several strains

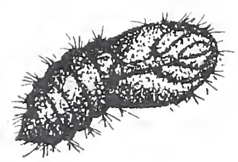
Gypsy Moth Life Cycle

Caterpillar
8 weeks during spring and early summer



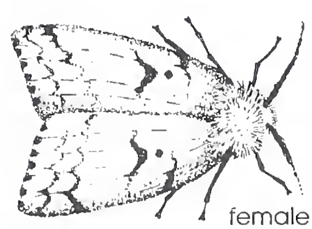
A young caterpillar is black. As it matures, double rows of red and blue spots develop. Insecticides usually are applied when foliage and caterpillars are at an early stage of development.

Pupa
2 weeks during spring-summer



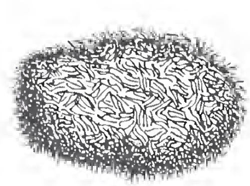
The female pupa is larger than the male. Both are dark reddish brown. Caterpillars pupate in protected areas, and pupae can be moved accidentally by people.

Adult
Several days during summer



The male adult is brown or gray and has feather-like antennae to detect the pheromone emitted by the female, which is white with small black markings.

Egg Mass
9 months, summer-spring



The female lays a buff-colored egg mass on almost any object. For this reason and because the egg is the longest lasting life stage, it is most often moved accidentally by people.

Figure 1-3. The caterpillar is the only life stage that causes defoliation; it is the target of most treatments.

that display considerable variability within populations. This variability is expressed in the ability of the female to fly and in the capacity to establish in a broad range of hosts (Wallner 1992).

The European and Asian strains of the gypsy moth are similar in appearance; however, behavioral differences between them may be significant. While the female of the European strain is flightless, some females of the Asian strain are strong fliers capable of flights exceeding 18 miles (28.9 km) (Wallner 1992).

Another difference between the strains is that females of the Asian strain are attracted to light and are more likely to deposit their eggs near light sources, thus potentially increasing the social "nuisance" factor usually associated with the gypsy moth (Hofacker 1994).

Because they feed on some hosts that are only marginally acceptable to the European strain, the Asian strain may have a greater potential to become established and may cause more extensive defoliation than the European strain (USDA APHIS 1992).

Other differences between the European and Asian strains are minor (*table 1-1*). The most reliable method to distinguish between the strains, other than the flight of the female, is genetic testing.

Before the first known introductions of the Asian strain in 1991, eradication actions had been taken only against the European strain. Eradication efforts for the European strain are conducted outside the generally infested area. Because the Asian strain has flight capabilities and a potentially broader host range, USDA policy is to eradicate moths exhibiting traits characteristic of, or genetic markers consistent with, the Asian strain wherever feasible, even inside the generally infested area when the source of the introduction is known. Knowledge of the time, location, and extent of an introduction will be required to trigger eradication of the Asian strain in the generally infested area. In cases where deductive, circumstantial, or investigative information can be developed about an introduction of uncertain origin, eradication may also be conducted. The goal is to eliminate only those gypsy moths that exhibit traits characteristic of the Asian strain in a specific area within the generally infested area.

Treatments available are the same for both strains, but the timing of application differs. Eradication of the European strain begins with a detection survey that locates isolated infestations. This detection survey is followed by a delimiting survey, to confirm the presence of established populations, and their approximate size and geographic extent. (See *app. B* for descriptions of these two types of survey.) Treatment follows the delimiting survey. The time from detection to initial treatment is 1-2 years.

Treatment for the Asian strain begins the year after detection. Time is not taken to conduct a delimiting survey. During that time an isolated infestation of the Asian strain could spread significantly because of the female's flight capability, resulting in the need for an even larger eradication project. In the year after an isolated infestation of the Asian strain is detected, the treatment area is determined using the best information available. The treatment area extends beyond the area where male moths were collected, taking into account the distance females might fly. After treatment, delimiting surveys are conducted throughout the treated area and well outside it.

Gypsy Moth Population Outbreaks

Populations of the gypsy moth periodically build to high levels for one or more years, then collapse and remain at low levels for varying periods of time. These changes in population levels pass through four phases (Doane and McManus 1981, USDA Forest Service 1989):

1. Innocuous phase—populations are low and stable. Predation by small mammals and birds, as well as parasitism by other insects, appear to keep populations low (Campbell 1976, Elkinton and Liebhold 1990).
2. Release phase—populations build rapidly within 1 or 2 years. While not fully understood, mild winters followed by warm dry springs and summers may increase survival and lead to population expansion and increase (Campbell and Sloan 1977c).

Table 1-1. Differences between the European and Asian strains of the gypsy moth, by life stage

Life Stage	European strain (North America)	Asian strain (Siberia, Russian Far East)
Caterpillars	First instars disperse	First and second instars disperse
	Color uniform	Color highly variable
	Main hosts: oak, birch, poplar, willow, alder	Main hosts: oak, larch, birch, willow
	Early instars feed in the canopy at night and move to resting sites during the day	Early instars feed in the canopy at night and remain on the host during the day
Pupae	Pupates in protected spots, in bark crevices, on leaf litter	Pupates on foliage
Adult females	Flightless	Strong flier, attracted to light
Egg masses	On tree trunks, rocks, leaf litter	On foliage, tree trunks, rocks, objects near lights
Mortality	Virus, *B.t.*, fungus, parasites, various predators	Virus, *B.t.*, fungus, microsporidia, numerous parasites and predators

(Adapted from Wallner 1992, p. 2)

3. Outbreak phase—populations reach high levels, and feeding causes widespread moderate to heavy defoliation of susceptible hosts. Although predation and parasitism of caterpillars continue, the impact on gypsy moth populations is minor. As the outbreak progresses, the gypsy moth virus—a naturally occurring nucleopolyhedrosis virus—or a fungus (*Entomophaga maimaiga*) may begin to build in the population and contribute to its collapse (Campbell and Sloan 1977c).
4. Decline phase—populations collapse as a result of overpopulation, starvation, infection by the virus or fungus, and decreased reproduction. Populations in this phase often have more males than females, whereas populations in the other phases have about equal numbers of males and females.

Host Plants

Caterpillars of the European strain of the gypsy moth eat a wide variety of foliage of trees and shrubs. They prefer oaks, apple, sweetgum, speckled alder, basswood, gray and white birch, poplar, willow, and hawthorn (McManus and others 1989). All instars feed on these species. Later instars feed on some species that early instars do not, such as cottonwood, hemlock, southern white cedar, and the pines and

During an outbreak caterpillars feed on almost all vegetation (McManus and others 1989).

spruces in the eastern United States. The gypsy moth normally does not feed on some plants, including rhododendron, laurel, dogwood, and yellow poplar. During an outbreak, however, gypsy moth caterpillars will feed on almost all vegetation (McManus and others 1989).

The Asian strain has a broader range of preferred hosts (USDA APHIS 1992) than does the European strain. Studies show that the Asian strain thrives better than the European strain on many of the host species in the United States. The greatest differences in growth rates have been observed on conifers, on which the Asian strain does better (Wallner 1994).

Laboratory feeding studies with both strains continue to determine the susceptibility of other plant species. *Appendix D* (Plant List) gives the suitability of 700 plant species to feeding by the gypsy moth.

Chapter 2

Alternatives Considered

Using the cyclone burner on gypsy moth caterpillars, circa 1891

Chapter 2
Alternatives Considered

Contents

This chapter presents a description and comparison of the program alternatives. First it describes the alternatives and how they were developed and identifies the preferred alternative.

Second, this chapter gives a comparison of the alternatives in terms of the consequences that would result from implementing them: expected future conditions and infestation status through the year 2010; how the alternatives respond to USDA's gypsy moth program goal; how they respond to issues; and the flexibility they provide in managing ecosystems.

Standard operational procedures and mitigating measures, which can compensate for adverse effects that might result from treatments, are outlined.

Description of the Strategies

Strategies used to manage the gypsy moth depend upon the infestation status of the area: generally infested, transition, or uninfested (*fig. 1-2*). The three strategies of suppression, eradication, and slow the spread—or their absence—make up the alternatives. In this section each strategy is described in detail, including where it would be conducted and the treatments available for use. Project history is included to give an idea of what future projects may be like.

Caterpillar droppings are an unwanted addition to a picnic. (Photo by Nate Bacon, photographer)

Suppression

Strategy and Objectives

Suppression prevents or minimizes heavy defoliation of trees by reducing outbreak populations of the gypsy moth in areas where the insect is already established. This strategy reduces effects of the gypsy moth on forest and urban ecosystems.

Objectives of suppression vary depending upon the resource(s) being protected. Minimizing tree defoliation, and thereby tree mortality, is a common objective. Another is reducing gypsy moth populations sufficiently so that treatments are not necessary the next season.

Tolerance for defoliation may vary (Twardus and Machesky 1992). Acceptable thresholds for gypsy moth population reduction may also vary, depending upon the type of treatment used and the resource being protected. For example, tolerance for gypsy moth effects appears to be much lower in areas where people live and recreate than in uninhabited forest. It is not uncommon to have two distinct standards for measuring treatment success—one for forested residential and recreation areas, and another for uninhabited forest (Maryland Department of Agriculture and USDA Forest Service 1994, Pennsylvania Department of Environmental Resources and USDA Forest Service 1994).

Suppression projects also may have specialized objectives, such as protecting habitat of threatened and endangered species, watersheds and water supplies, and areas with historic significance.

Implementation

Participation of State or Federal agencies in cooperative suppression projects is voluntary, and not

all States or Federal agencies choose to participate in any given year. State and Federal agencies normally discuss with the Forest Service their anticipated suppression needs for the coming spring by fall each year, according to established guidelines and procedures (USDA Forest Service 1994a). Generally speaking, private landowners may also participate in cooperative gypsy moth suppression projects with the Forest Service through State agencies.

The Forest Service contributes 100 percent of the cost of conducting suppression on National Forest System lands and on other Federal lands. Costs of conducting cooperative suppression projects are shared with non-Federal cooperators in the amount and manner determined appropriate by the Secretary of Agriculture (USDA Forest Service 1993c).

Between 1980 and 1994 more than $156 million was spent to conduct suppression projects on Federal, State, and private lands in the generally infested area. Approximately 44 percent of that total was Federally financed with the remainder provided by State, county, and private sources (USDA Forest Service 1994d).

Treatments Available

Treatments available for suppression projects are two biological insecticides, *Bacillus thuringiensis* var. *kurstaki* (*B.t.k.*) and the gypsy moth nucleopolyhedrosis virus (Gypchek), and one chemical insecticide, diflubenzuron. Although results vary by insecticide, each successfully achieves desired suppression objectives in the majority of the projects in which it is used. All three are registered by the U.S. Environmental Protection Agency (U.S. EPA). Other insecticides may also be registered by the U.S. EPA for use against the gypsy moth; however, they are not available for use in cooperative suppression projects. A detailed discussion of treatments is in *appendix A*.

Insecticide use evolved during the 1980's as improvements continued with *B.t.k.* and diflubenzuron formulations, with the availability and use of Gypchek, and as concerns about human health and safety, and the effects on nontarget organisms increased. Between 1981 and 1995 the amount of *B.t.k.* and diflubenzuron used fluctuated year to year in relation to each other. The period 1986 to 1995 showed a definite upward trend in the amount of biological insecticides (*B.t.k.* and Gypchek) used as a proportion of total acres treated (*fig. 2-1*). In 1995 biological insecticides were used on two-thirds of the acreage treated and diflubenzuron on only one-third of the acreage treated.

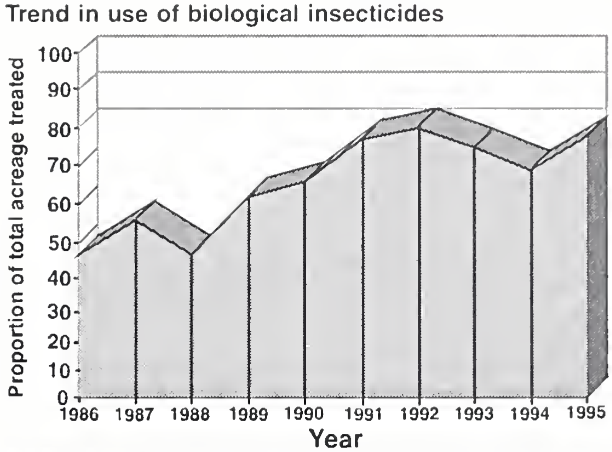


Figure 2-1. The use of biological insecticides *B.t.k.* and Gypchek has risen steadily as a proportion of the acreage treated annually to suppress gypsy moth populations.

The choice of which insecticide to use and the constraints, if any, guiding that use are made at the local level for each project, often with input from the people who live in or near the proposed treatment areas. None of the insecticides are applied indiscriminately over large forested areas. Rather each has an appropriate place and circumstances for use.

The overall guide for how an insecticide is applied begins with the U.S. EPA-approved insecticide label, which describes where and how the insecticide can be applied and for what pest. In cooperative gypsy moth suppression projects, State and Federal project managers also examine the desired project objectives in balance with concerns about effects on nontarget organisms, including potential effects on rare or threatened and endangered species, human health and safety, and effects on environmentally sensitive areas. Often this examination results in a switch to another insecticide, modification of treatment area boundaries, implementation of buffer zones, and development of mitigating measures to further protect people and the environment. Such an examination is part of the site-

specific environmental analysis process that is required for each proposed treatment project and tiered to this environmental impact statement.

Diflubenzuron may not be applied directly to water according to the insecticide label. In practice diflubenzuron is not used within 200 to 1000 feet of open water or estuaries because of its potential impacts on aquatic invertebrates (Delaware Department of Agriculture and USDA Forest Service 1995, Maryland Department of Agriculture and USDA Forest Service 1994, Pennsylvania Department of Environmental Resources and USDA Forest Service 1994, West Virginia Department of Natural Resources and USDA Forest Service 1995). *B.t.k.* and Gypchek, however, are often used where diflubenzuron is not or cannot be used, including up to the water's edge. Insecticide selection and any restrictions on the application of that insecticide, such as setting buffer zones around water bodies, are determined at the project level and typically with public input.

Where Suppression Would Be Conducted

In 1994, all or portions of 16 States and the District of Columbia made up the generally infested area (*fig. 1-2*). More counties and States are added to the generally infested area as the gypsy moth spreads. For example, in 1994 seven counties in Ohio and two counties in Virginia were added.

In theory, suppression projects could be conducted anywhere in the generally infested area where gypsy moth population levels are likely to cause defoliation. In practice, some areas are more likely to be treated than others.

Cooperative gypsy moth suppression projects on State and private lands have been conducted in four general areas: places where people live, recreation areas, uninhabited or sparsely inhabited forests or woodlots, and special use areas (Schneeberger 1994a). Generally speaking, areas where people live and recreate receive the highest priority for treatment.

- The first treatment category, places where people live, has commonly been categorized as forested residential areas, wooded residential areas, forested communities, residential developments, or simply residential areas. These areas typically have 50 percent or more canopy cover in tree species moderately to highly preferred by the gypsy moth. These areas include typical housing developments in suburban and rural areas, discrete woodlots containing one or more homes, and individual homes along roadsides. Nearly two-thirds of the acreage treated in cooperative suppression projects in 1993 was in places where people live.
- The second treatment category, recreation areas, includes public and privately owned campgrounds, picnic areas, roadside rest areas, parks, hiking trails, scenic areas, and camps.
- The third treatment category, uninhabited or sparsely inhabited forests or woodlots, includes managed forest stands, watershed areas, fish and game lands, tree farms, and commercial forests. Recreation and forested areas represented about one-third of the acreage treated in cooperative suppression projects in 1993.
- The fourth treatment category, special use areas, includes historic or natural landmark sites, scenic areas, critical habitat of threatened or endangered species, experimental forests, and watersheds for public water supplies.

Treatment priorities on Federal lands vary. In National Forests, treatment priorities tend to be habitat of threatened or endangered species, recreation areas, and unique ecosystems, followed by administrative sites, high value forest stands, and

Acres of Suppression, 1970-1994

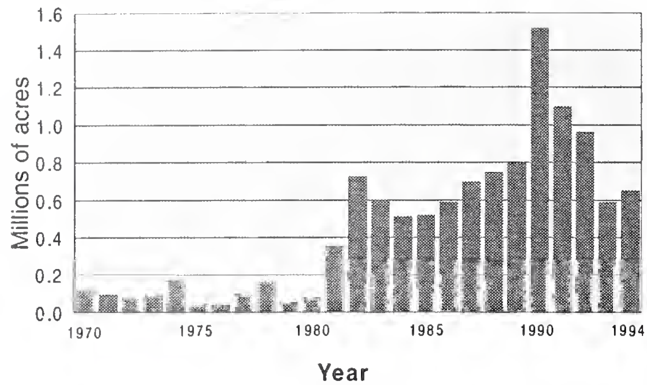


Figure 2-2. The number of acres treated annually increased significantly in the early 1980's, peaking in 1990 at over 1.5 million acres.

others. On other Federally administered lands treatment priorities vary by site and agency.

Suppression Project History

Gypsy moth cooperative suppression projects date back to at least 1970 when State agencies in Pennsylvania and New Jersey, responding to record defoliation levels from the previous summer, treated 122,518 acres (49,582 ha). From 1970 to 1994 a total of 11.4 million acres (4.6 million ha) in 15 States was treated by Federal and State agencies (*fig. 2-2*).

Between 1989 and 1994 5.6 million acres (2.2 million ha) were treated for suppression of gypsy moth populations in 13 States and the District of Columbia (USDA Forest Service 1994d). About 4.7 million acres (1.9 million ha) or about 84 percent of those acres were on State and private lands, treated through cooperative suppression projects with State agriculture or natural resource agencies. The remaining 16 percent were on National Forests, national parks, American Indian lands, national wildlife refuges, military reservations, and other Federally administered lands (USDA Forest Service 1994d).

In 1986, a Gypsy Moth Treatment Monitoring Database was developed by the USDA Forest Service, Northeastern Area to record and provide information on project operations and results. In Delaware, Maryland, New Jersey, Pennsylvania, Vermont, Virginia, and West Virginia, foliage protection objectives (defoliation kept to 30 percent or less) were achieved about 94 percent of the time (Twardus and Machesky 1992). Population reduction objectives (egg mass numbers reduced below 500 egg masses per acre or 1236 per hectare) were achieved about 70 percent of the time.

Eradication

Strategy and Objectives

Eradication prevents establishment of the gypsy moth in new areas by eliminating isolated infestations. Isolated infestations are indicated by: (1) male moths caught in traps; (2) the presence of other life stages; or, (3) a pattern of male moth catches that indicate a reproducing population. It is often hard to find life stages of the insect other than the male moths. Localized defoliation of trees may occur, but only when an infestation is not detected for several seasons, or because site and climate are highly suitable for increases in gypsy moth numbers.

The goal of eradicating isolated infestations of the European strain of the gypsy moth is to prevent it from becoming established through artificial spread into the uninfested area. The goal of eradicating introductions of the gypsy moth that exhibit traits characteristic of the Asian strain is to prevent it from becoming established anywhere in the United States.

To date, all eradication projects that have been completed have been successful in eliminating isolated infestations outside the generally infested area, although some required more than one attempt. Catching no male moths in pheromone traps for two consecutive years indicates that eradication has been achieved.

Implementation

Eradication has been a fundamental strategy in USDA's gypsy moth program. It complements a gypsy moth regulatory program, which seeks to prevent the artificial spread of the insect on outdoor household articles, nursery stock, Christmas trees, and other commodities, from the generally infested area to uninfested areas of the United States. (*Appendix B* describes regulatory and other activities that comprise the gypsy moth program.) The movement of outdoor household articles from the generally infested area to uninfested areas of the country was the most common means of spreading the European strain of the gypsy moth from 1980 to 1995. Over 85 percent of all isolated infestations can be traced to the movement of outdoor household articles (USDA APHIS 1990). In recent years an increasing number of isolated infestations are the result of infested nursery stock shipments.

Eradication projects are usually planned and carried out in cooperation with State agriculture and natural resource agencies. The USDA does not require private landowners to participate in eradication projects. Participation is governed by State law, and the policies and regulations of the cooperating State agency. For example the California Department of Food and Agriculture (CDFA)

conducts gypsy moth eradication activities under the guidance of an environmental impact report prepared by that agency in compliance with the California Environmental Quality Act. These activities are often carried out solely by CDFA with no assistance from USDA. Similarly others may conduct gypsy moth suppression or possibly even slow-the-spread activities without USDA participation.

In some States, participation in eradication projects may be mandatory. If State actions are determined to be inadequate, the USDA has the authority to impose a quarantine of private, State, tribal, or Federal lands if necessary. In addition, the Secretary of Agriculture has the authority under the Federal Plant Pest Act to declare an extraordinary emergency, which would permit treatment of all infested lands.

During the period 1988-1993, $8.7 million was spent on gypsy moth eradication projects on over 301,000 acres (122,000 ha) in the United States. Three-fourths of the cost associated with eradication during that period was Federally funded. The remaining 25 percent was paid by States or other cooperators. Compared with costs of eradicating the European strain of the gypsy moth, costs of eradicating the Asian strain have been higher because of the larger area surveyed and treated.

Treatments Available

Treatments available for eradication projects are two biological insecticides—*B.t.k.* and the gypsy moth nucleopolyhedrosis virus (Gypchek)—and one chemical insecticide—diflubenzuron; and treatments employing mass trapping, mating disruption, and the sterile insect technique. Typically an integrated pest management (IPM) approach using one or more of these treatments over two or more consecutive years is necessary to complete an eradication project. The smaller the project area the more likely mass trapping (a noninsecticidal method) can be used to eliminate the infestation. In situations where a second or third follow-up control measure is implemented in the same year, that control measure is usually mass trapping (USDA APHIS 1994). A detailed discussion of these treatments is in *appendix A*.

Insecticide use in cooperative gypsy moth eradication projects has shown a trend similar to that in suppression projects, in that former use of broad spectrum chemical insecticides has given way to use of *B.t.k.*, noninsecticidal means like mass trapping and mating disruption, Gypchek, and diflubenzuron. Between 1993 and 1995 eradication was conducted on nearly 200 sites in 16 States. The majority involved application of *B.t.k.*, Gypchek, or noninsecticidal methods. Diflubenzuron was used on only two sites in 1993 and five sites in 1995. No broad spectrum insecticides have been used in cooperative eradication projects since 1989 (USDA APHIS 1994).

Where Eradication Would Be Conducted

Eradication projects may be conducted in any area of the United States where the insect is not permanently established. For the European strain, this is the uninfested area, outside of the generally infested area and ahead (west and south) of the transition area. The Asian strain of the gypsy moth may be eradicated anywhere, including the generally infested area when the location, extent, and time of the introduction are known. *Figure 2-3* shows where eradication projects were conducted between 1967 and 1994.

The risk of gypsy moth introductions in an area indicates the likelihood of eradication projects in that area. The following areas are categorized in order of decreasing risk of gypsy moth introduction and establishment (USDA APHIS 1990):

- Areas that receive regulated articles from generally infested areas and are exposed to movement of infested vehicles, including areas with sawmills and veneer mills, nurseries, mobile home parks, State and Federal parks, campgrounds, and tourist attractions.
- Areas with suitable host trees to support gypsy moth infestation in wooded residential areas, in residential areas with high incidences of relocation by people, and in cities with military bases or major universities. Examples are areas surrounding large

Location of eradication projects, 1967-1994

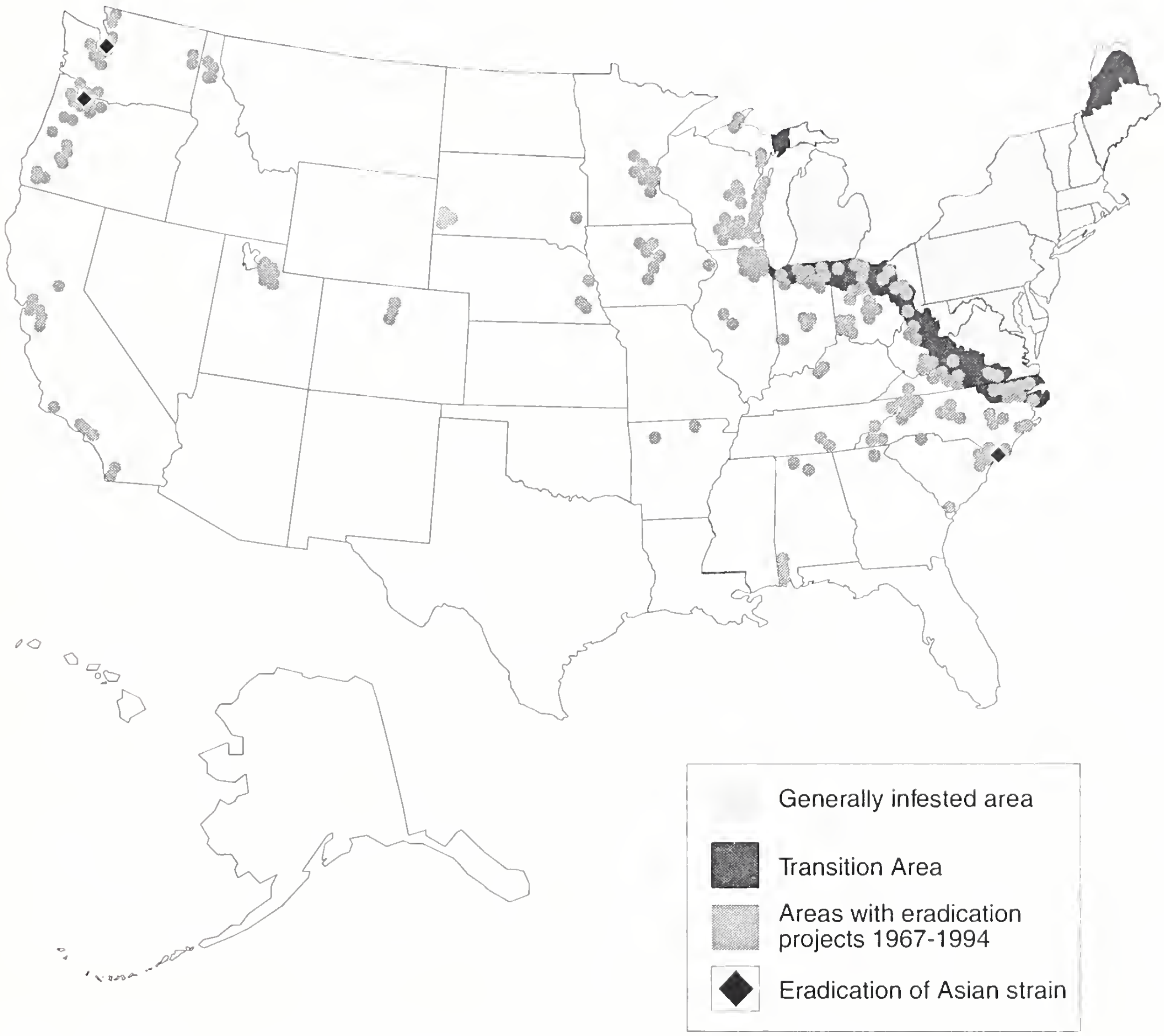


Figure 2-3. The generally infested area has expanded masking areas in that part of the country where eradication projects were conducted before 1994.

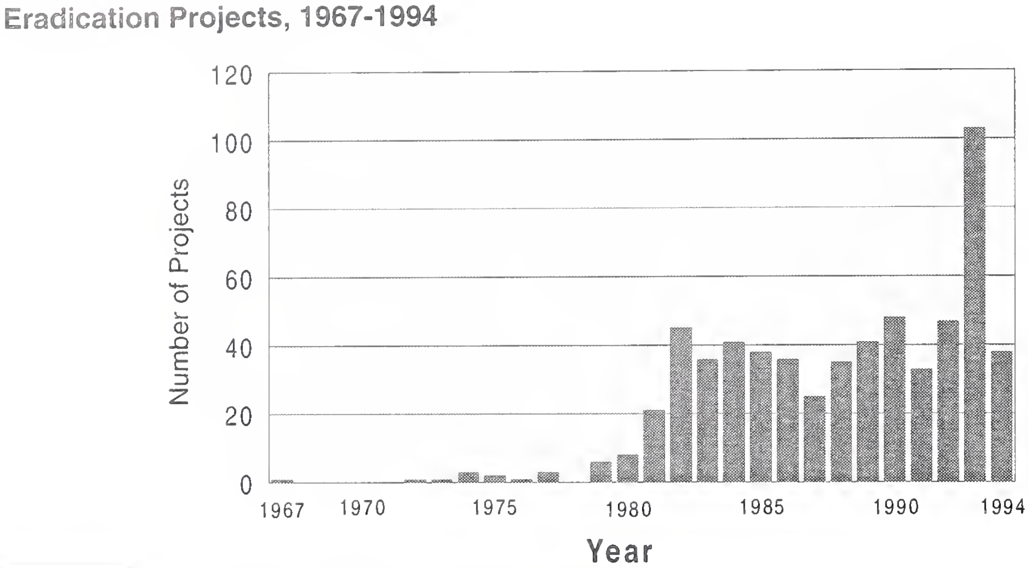


Figure 2-4. The dramatic increase in the number of eradication projects conducted each year since the early 1980's follows the largest recorded outbreaks of the gypsy moth by 2 to 3 years and the near doubling of the number of States in the generally infested area.

metropolitan areas such as Chicago, San Francisco, Louisville, Atlanta, Raleigh, Salt Lake City, and Seattle.

- Areas with suitable habitat to support a gypsy moth infestation in contiguous wooded areas that are accessible to people, in areas with moderate populations such as small cities, and in large urban areas with few trees. Examples are the Blue Ridge areas of Virginia, West Virginia, Tennessee, North Carolina, and Georgia; the Ozark areas of Missouri and Arkansas; and the hardwood regions of Wisconsin and Minnesota.
- Areas with suitable habitat to support gypsy moth infestations and a low risk of introduction such as rural agricultural areas with widely scattered small towns and noncontiguous wooded areas. Examples are the corn belt areas of Iowa, Illinois, Indiana, and Ohio.
- Areas with a lack of suitable habitat or potential for introduction. Such areas might include the Great Plains grassland-wheat area, semi-arid high desert areas, and dry desert areas.

Introductions are possible, even where there is a general lack of suitable habitat. Other areas vulnerable to introductions of the gypsy moth are ports (air and sea) and border crossings.

Eradication Project History

From the earliest control efforts in 1890 in Massachusetts to efforts in the late 1950's, gypsy moth programs were aimed at containing the spread of the insect with the ultimate goal of eliminating it from the United States. By the early 1960's all hopes of achieving this degree of eradication were abandoned (McManus and McIntyre 1981). Since that time, the gypsy moth has successfully increased its range, primarily through natural spread but also by human-aided artificial spread. Preventing artificial spread has become more difficult due to the increased mobility of households, the recreational and residential development of areas that were once forests, and the fact that one of the places female gypsy moths lay egg masses is on outdoor household articles, such as picnic tables or campers, that people transport when they move.

Figure 2-4 shows the number of eradication projects each year from 1967 to 1994. Over 90 percent of the total number of eradication projects since 1967 have occurred since 1981 (USDA APHIS 1994). The increase in eradication activity may be due to factors such as these: the use of higher quality detection tools; implementation of better monitoring programs; and increased gypsy moth activity in the generally infested area since 1980 (the number of

States generally infested nearly doubled between 1980 and 1994).

Nearly 85 percent of the eradication sites involved less than 1000 acres (405 ha) each, and more than half of those were 100 acres (40 ha) or less (USDA Forest Service 1994d). Occasionally an isolated infestation is not detected until it has grown significantly. The largest eradication project since the late 1950's occurred in Lane and Douglas counties, Oregon. From 1984 to 1986 as many as 200,000 acres (80,939 ha) were treated per year with three applications of *Bacillus thuringiensis* var. *kurstaki* (*B.t.k.*). The infestation was successfully eliminated, as no male moths have been caught in Douglas County and only a few single moth catches have been detected in Lane County (Mudge 1993). Eradication of this isolated infestation demonstrated that it is possible to successfully eradicate large isolated infestations, and that *B.t.k.* is an effective eradication treatment. Eradication projects of over 10,000 acres (4,047 ha) for the European strain made up 2 percent of all the eradication projects conducted between 1981 and 1994, but 69 percent of the total number of acres (963,458 acres or 389,911 ha) treated.

Eradication projects for the Asian strain of the gypsy moth cover large areas, to take into account the flight capability of the female. As of 1995, two eradication projects for the Asian strain have been initiated. An eradication project in Oregon and Washington State covered approximately 120,000 acres (48,000 ha) and spanned a 3-year period (1992-1994). Another project was begun in North Carolina in 1994 on approximately 140,000 acres (56,000 ha). In 1995, 5,740 acres (2,323 ha) were treated. *B.t.k.* was the primary insecticide used in both eradication projects for the Asian strain. Eradication has been achieved in Oregon and Washington. The project in North Carolina will be closely monitored to determine if more follow-up treatments are necessary.

Infested vehicles spread the gypsy moth to new areas.

Slow the Spread

Strategy and Objectives

The slow-the-spread strategy is designed to slow the spread of the European strain of the gypsy moth by keeping low-level populations from rapidly increasing. Slow the spread involves intensive monitoring and aggressive management of building gypsy moth populations in the transition area. The objective is to delay the impacts and costs associated with gypsy moth outbreaks and suppression.

As of December 1994 the slow-the-spread strategy was unproven but being evaluated by the Forest Service and APHIS in portions of North Carolina, Virginia, West Virginia, and the Upper Peninsula of Michigan, under the Slow-the-Spread Pilot Project. If the strategy proves successful, it would reduce the growth of the generally infested area, which grew by 5.3 million acres (2.1 million ha) between 1989 and 1994.

Background

Historically, the transition area has been ignored in terms of survey and treatment because gypsy moth populations in that area are recently established. The populations are not yet at damaging levels so they do not meet the criteria for suppression, yet they are too close to the generally infested area to meet eradication objectives. Each spring when gypsy moth caterpillars hatch, they disperse naturally from the generally infested area to the transition area. A certain amount of human-aided local movement of the gypsy moth occurs as well, which may result in the establishment of small pockets of low-level infestations in the transition area. These pockets of infestation are generally not at damaging levels. The problem in leaving them untreated is that some will continue to grow, will coalesce, and will contribute to further spread.

Before 1966, the rate of spread of the gypsy moth was estimated to be 2 to 6 miles (3 to 10 km) per year. From 1966 to 1990 the rate of spread was

estimated at 13 miles (21 km) per year (Liebhold and others 1992). This apparent increase in the rate of spread is of concern, because the first outbreak in a previously uninfested area is often the most severe and usually results in a large suppression effort.

Three major USDA initiatives have led to the development of the slow-the-spread strategy. From 1975 to 1978, the first initiative consisted of a multidisciplinary research, development, and application program to (1) identify and examine the natural processes operating against the gypsy moth and (2) further evaluate treatment methods to use against low-to-high populations of the insect. The goal of that program was to incorporate emerging technology into an IPM system (McManus and McIntyre 1981).

The second initiative, the Maryland IPM Gypsy Moth Project, was conducted between 1983 and 1987. Its major objective was to determine the feasibility of managing gypsy moth populations using an IPM approach over a wide range of ecological, geographical, and land-use areas in a five county area of Maryland (Reardon and others 1993).

The Appalachian Integrated Pest Management (AIPM) Gypsy Moth Demonstration Project, the third initiative, was implemented between 1987 and 1992 over a 38-county region in West Virginia and Virginia (USDA Forest Service 1994e). One of the objectives of the AIPM Project was to demonstrate that it is feasible to slow the spread of the gypsy moth over a large area. It demonstrated that the effectiveness of a slow-the-spread strategy requires coordination of the efforts of private landowners and public agencies involved.

The Slow-the-Spread Pilot Project represents the fourth and most recent USDA initiative. During 1994 a total of 34,309 acres (13,885 ha) was treated using the slow-the-spread strategy after detection monitoring on 6.5 million acres (2.6 million ha).

Economic analysis has indicated that $100 million to $500 million in benefits could be realized over a 25-year period, by slowing the spread of the gypsy moth (Leuschner 1991). Because a smaller new area would become generally infested each year, the potential benefits would accrue largely from fewer effects due to the gypsy moth in residential areas and less suppression than would otherwise be required. Reduced effects on timber and recreation were less than 10 percent of the potential benefits. Until the Slow-the-Spread Pilot Project is completed and the data are analyzed, however, it will not be known whether the rate of spread can be reduced, and to what degree. Results of the project will provide the means to compare the rate of spread throughout the pilot project area with that in other areas or with model predictions, and determine whether the benefits of a reduced rate of spread are worth the costs of monitoring and treatment.

The only data available for estimating the costs of a slow-the-spread strategy are from the Slow-the-Spread Pilot Project. The 1994 monitoring costs involved the placement and servicing of 34,000 male moth traps over 6.6 million acres (2.7 million ha) at a total cost of $1,511,516. Treatment of 34,309 acres (13,885 ha) cost $649,358.

Treatments Available

Treatments available for slow-the-spread projects are the insecticides *B.t.k.*, diflubenzuron, and the nucleopolyhedrosis virus (Gypchek); and noninsecticidal methods employing mass trapping, mating disruption, and the sterile insect technique. A detailed discussion of these treatments is in *appendix A*.

Where Slow the Spread Would Be Conducted

The slow-the-spread strategy would be conducted in the transition area. In this area individual trap captures of male moths are low and pockets of trap captures that suggest low-level infestations are scattered between the generally infested and uninfested areas; other life stages are scarce. With extensive survey efforts, pockets of gypsy moth infestations may be found as close as 1 mile (1.6 km) apart and as far as 50 miles (80.2 km) apart. Tree defoliation due to the gypsy moth is uncommon in this area and is limited to single trees or small groups of trees.

In 1994 the transition area was a band about 50 to 100 miles (80.5 to 160.9 km) wide extending from eastern North Carolina northwestward through Virginia, West Virginia, and Ohio, then west through northern Ohio and northern Indiana. The area also included the Upper Peninsula of Michigan and a portion of Maine (*fig. 1-2*). The width of the transition area varies from year to year depending on geographic and climatic conditions, and whether gypsy moth population outbreaks occur. Exactly

Pheromone-baited traps are used to detect low-level gypsy moth populations.

where slow the spread would be implemented would depend on the yearly fluctuations and dispersal of gypsy moth populations.

Within the transition area gypsy moth populations would be monitored using pheromone traps placed in a grid pattern. Pheromone traps are the most effective tool available to detect low-level populations. Areas are evaluated for treatment when patterns of male moth captures suggest the presence of pockets of low-level infestations that may contribute to further population buildup and expansion of the generally infested area.

In areas where gypsy moth populations meet treatment thresholds, success of the slow-the-spread strategy would require coordinated action. Federal agencies, American Indian tribes, States, counties, private and industrial landowners, and interested groups and individuals within the transition area would need to work together to achieve the common goal of slowing the spread of the gypsy moth.

Alternatives Considered

Ten alternatives were formulated in response to comments received through public involvement. (See *appendix C* for a summary of the comments.) Eight alternatives are unique combinations of the three strategies—suppression, eradication, and slow the spread. One alternative maintains USDA technical assistance activities but includes no strategies. Another alternative discontinues all USDA involvement in gypsy moth management activities.

Alternatives Considered but Not Carried Forward

Four of the ten alternatives were not carried forward for analysis in this environmental impact statement:

- Slow the spread only
- Suppression and slow the spread
- Discontinuing the gypsy moth program
- Eradication from the United States.

Slow the Spread Only

Description

This alternative of slow the spread only describes a program that would allow the Forest Service and APHIS to make a coordinated effort to slow the spread of the gypsy moth by conducting treatments in the transition area. The Forest Service would not participate in suppression. The Forest Service and APHIS would not participate in eradication. Technical assistance and support could be provided to States and other Federal agencies through existing programs.

Reasons for Elimination

The benefits of slow-the-spread activities result from delaying the need for suppression. Therefore, without suppression in this alternative slow the spread would provide no benefit. The alternative of slow the spread only also does not provide for treatment of isolated infestations. Without such treatment isolated infestations would reach defoliating levels and begin to spread, new generally infested areas would appear

and require suppression, and the generally infested area would expand in a patchwork pattern. Slowing the rate at which the generally infested area expands naturally without preventing establishment of isolated infestations would defeat the purpose of slow the spread.

Suppression and Slow the Spread

Description

This alternative of suppression and slow the spread describes a program to suppress gypsy moth outbreaks, as well as to slow the spread of the insect. Eradication of isolated infestations would not be pursued by USDA.

Reasons for Elimination

The objectives in this alternative—to minimize damage and to delay the advance of the gypsy moth across the United States—are independent of each other and apply to different parts of the country. Without eradication, new generally infested areas would appear as isolated infestations become established and begin to spread. Although outbreak populations would be eligible for treatment in the generally infested area, allowing isolated infestations to become established in the uninfested area would defeat the purpose of slow the spread.

Discontinuing the Gypsy Moth Program

Description

This alternative discontinues all gypsy-moth-related activities in USDA's gypsy moth program. In addition to the suppression, eradication, and slow-the-spread strategies, regulatory programs and the other activities described in *appendix B* would also be discontinued.

Reasons for Elimination

This alternative of discontinuing the gypsy moth program does not meet the USDA goal of reducing the adverse effects of the gypsy moth nationwide.

Eradication From the United States

Description

This alternative describes a national effort to eradicate the gypsy moth from anywhere in the United States. Such an effort would require cooperation between all Federal and non-Federal agencies, States, and private citizens, and coordination with Canada. Participation in such a program would have to be mandatory for it to be effective. Eradication of the gypsy moth from the United States would require many years of concerted effort.

Reasons for Elimination

Although some public comments supported the idea of eradicating the gypsy moth from the United States, this alternative was eliminated on the basis of past experience. When only seven States were infested in the 1950's, attempts to eradicate the gypsy moth from all of them failed. Now that more States are infested, any further attempt to eradicate the gypsy moth from the United States is unlikely to succeed. In addition, this alternative would be extremely costly and probably would not be publicly acceptable.

Alternatives Considered in Detail

These six alternatives were considered in detail:

- No suppression, no eradication, no slow the spread
- Suppression
- Eradication
- Suppression and eradication
- Eradication and slow the spread
- Suppression, eradication, and slow the spread (preferred).

Each alternative is presented as a national gypsy moth management program.

One USDA activity common to all the alternatives is the delivery of technical assistance to State and Federal cooperators. This assistance could include the following: assisting in planning and conducting gypsy moth detection surveys and evaluations; developing gypsy moth management

Table 2-1. Treatment options available with alternatives considered in detail

Treatment[2] options	1	2 S	3 E	4 S	4 E	5 E	5 STS	6 S	6 E	6 STS
Insecticide treatment										
Bacillus thuringiensis var. *kurstaki*		●	●	●	●	●	●	●	●	●
Diflubenzuron		●	●	●	●	●	●	●	●	●
Gypsy moth virus		●	●	●	●	●	●	●	●	●
Noninsecticidal treatment										
Mass trapping			●		●	●	●		●	●
Mating disruption			●		●	●	●		●	●
Sterile insect release			●		●	●	●		●	●

Alternative and strategy[1]

[1] **S** = suppression strategy: Reduce damage caused by the gypsy moth in the generally infested area
E = eradication strategy: Prevent establishment of isolated infestations of the gypsy moth
STS = slow the spread strategy: Slow the spread of the gypsy moth in the transition area
[2] No treatment is an option in all the alternatives.

plans and recommendations; assisting in planning suppression, eradication, and slow-the-spread projects; assisting in contracting for insecticide applications; assisting in aerial application technology, such as aircraft calibration and characterization; assisting in developing plans for monitoring insecticide applications; conducting posttreatment evaluations; and training. The assistance provided would vary depending on cooperator needs and requests, and on available funding.

All alternatives offer USDA support for an integrated pest management approach to managing the gypsy moth in the United States. In keeping with this approach, different treatment options are available (*table 2-1*).

Federal agencies must consult with the U.S. Fish and Wildlife Service or the U.S. Department of Commerce's National Marine Fisheries Service before authorizing, funding, or implementing any action that may jeopardize the continued existence of a listed (endangered or threatened) species (50 CFR 17.11 and 17.12) or a species proposed for listing (most current Federal Register Notice of Review). This includes the destruction or adverse modification of critical habitat (Endangered Species Act of 1973 as amended [16 U.S.C. 1531 et seq.]). These consultations with the Fish and Wildlife Service or the National Marine Fisheries Service take place at the site-specific or project level.

The alternatives define how the USDA would respond to the gypsy moth, and do not address actions that may be taken by others.

For the reader's handy reference, the alternatives and strategies are also defined on the front inside cover.

Alternative 1. No Suppression, No Eradication, No Slow the Spread

Under alternative 1, the Forest Service and APHIS would not suppress, eradicate, or slow the spread of the gypsy moth (*fig. 2-5*).

Implementation of alternative 1 would not reduce damage, prevent establishment, or slow the spread of the gypsy moth.

Alternative 2. Suppression

Under alternative 2, the Forest Service could conduct suppression projects and cooperate with other Federal agencies and States to conduct suppression projects (*fig. 2-6*).

The Forest Service and APHIS would not slow the spread in the transition area, and neither would eradicate isolated infestations.

Implementation of alternative 2 would help reduce damage caused by the gypsy moth in the generally infested area.

Alternative 3. Eradication

Under alternative 3 the Forest Service and APHIS could conduct eradication projects and cooperate with other Federal agencies and States to conduct eradication projects (*fig. 2-7*).

The Forest Service would make no coordinated effort to suppress the gypsy moth in the generally infested area. The Forest Service and APHIS would not slow the spread in the transition area.

Implementation of alternative 3 would prevent establishment of gypsy moth populations in the uninfested area. The Asian strain of the gypsy moth would be eradicated wherever it is found, including the generally infested area when the source of the introduction is known.

Alternative 4. Suppression and Eradication

Under alternative 4 the Forest Service could conduct suppression projects and cooperate with other Federal agencies and States to conduct suppression projects. The Forest Service and APHIS could conduct eradication projects, and cooperate with other Federal agencies and States to conduct eradication projects (*fig. 2-8*). This alternative proposes the continuation of gypsy moth strategies currently being implemented. Alternative 4 represents the "no action" alternative in that it would be no change from the current program.

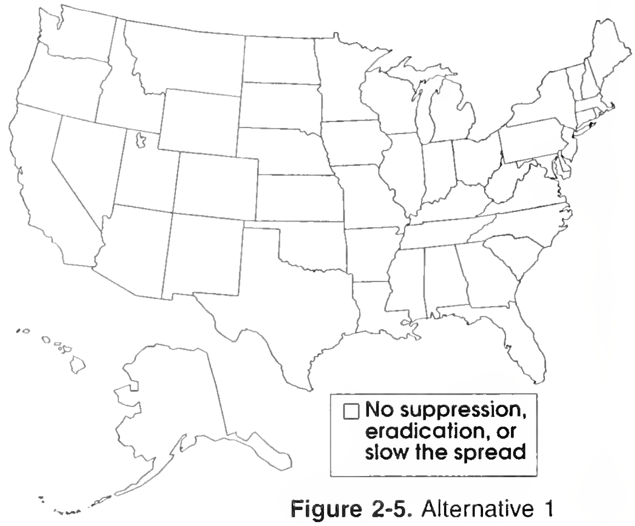


Figure 2-5. Alternative 1

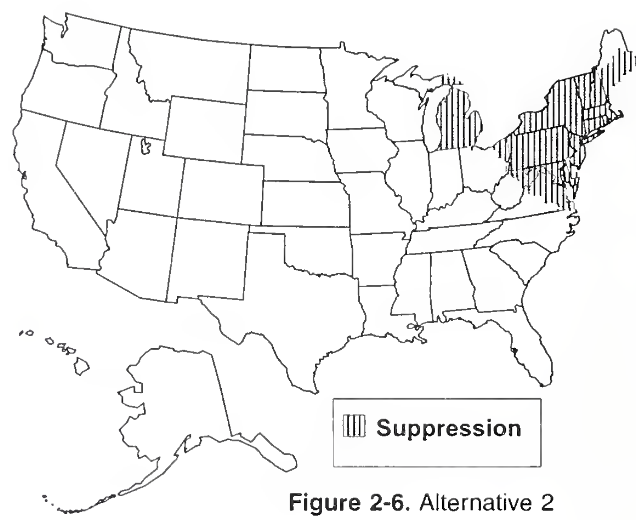


Figure 2-6. Alternative 2

Figure 2-7. Alternative 3

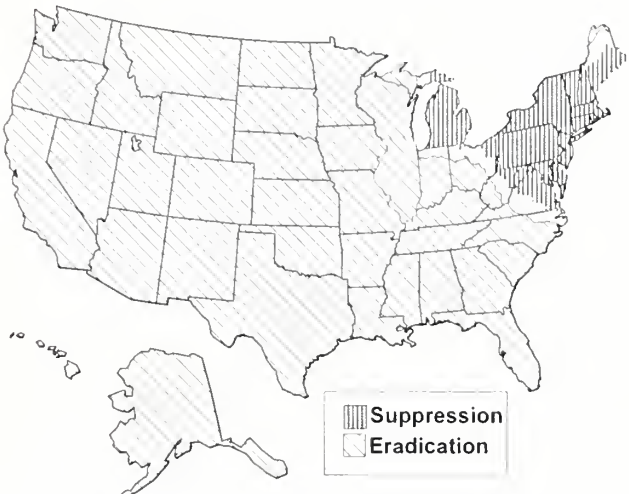


Figure 2-8. Alternative 4

Figure 2-9. Alternative 5

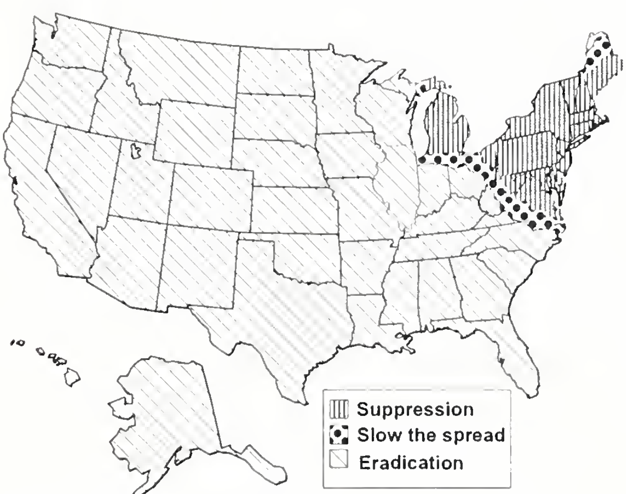


Figure 2-10. Alternative 6

USDA agencies would make no coordinated effort to reduce the rate of spread of the insect in the transition area.

Implementation of alternative 4 would reduce damage caused by the gypsy moth in the generally infested area and prevent establishment of gypsy moth populations in the uninfested area. The Asian strain of the gypsy moth would be eradicated wherever it is found, including the generally infested area when the source of the introduction is known.

Alternative 5. Eradication and Slow the Spread

Under alternative 5 the Forest Service and APHIS could conduct eradication and slow-the-spread projects, and cooperate with other Federal agencies and States to conduct eradication and slow-the-spread projects (*fig. 2-9*).

The Forest Service would make no coordinated effort to suppress outbreak populations of the gypsy moth in the generally infested area.

Implementation of alternative 5 would prevent establishment of gypsy moth populations in the uninfested area and slow the natural spread of the insect in the transition area. The Asian strain of the gypsy moth would be eradicated wherever it is found, including the generally infested area when the source of the introduction is known.

Alternative 6. Suppression, Eradication, and Slow the Spread (Preferred)

Under alternative 6 the Forest Service could conduct suppression projects, and cooperate with other Federal agencies and States to conduct suppression projects. The Forest Service and APHIS could conduct eradication and slow-the-spread projects and cooperate with other Federal agencies and States to conduct eradication and slow-the-spread projects (*fig. 2-10*). Alternative 6 is the preferred alternative.

Implementation of alternative 6 would help reduce damage in the generally infested area, prevent establishment of gypsy moth populations in the uninfested area, and slow the natural spread of the insect in the transition area. The Asian strain of the gypsy moth would be eradicated wherever it is found, including the generally infested area when the source of the introduction is known.

Evaluation and Comparison of Alternatives

In this chapter the alternatives are compared based on environmental consequences, expected future conditions, how they respond to the goal of USDA's gypsy moth program, how they respond to issues, and the flexibility they provide for managing ecosystems. The environmental consequences of each of the alternatives are described in *chapter 4 part C.*

Environmental consequences are presented in a programmatic context at a national scale, for projects that may be conducted. Before treatment projects could be implemented site-specific environmental analyses must be conducted for circumstances unique to each project.

Expected Future Conditions

The infestation status of parts of the country in the future is an important factor to consider when comparing alternatives. The year 2010 was selected to display reasonably foreseeable long-term conditions. Predictions of infestation status by the year 2010 are based on information found in historic records of defoliation, of the size of the generally infested area, and of USDA suppression and eradication projects (Liebhold and others 1992, USDA Forest Service 1994a,d).

Predicting Gypsy Moth Spread

Gypsy moth spread in the future is expected to follow the same pattern as it did from 1966 to 1990. Historical data on the generally infested area were extracted from the annual Code of Federal Regulations as described by Liebhold and others (1992). Two historical spread rates (7.6 km/yr in cold northern counties and 20.8 km/yr in southern warm counties) were applied to the existing generally infested area in a geographic information system (GIS), to predict the extent of the area for 1995-2010. For each year (both past and present), infested counties were identified and each of their areas was multiplied by the proportion of the infested area that is forested by susceptible stands (where preferred tree species represent more than 20 percent of the basal area), and these areas totaled to derive an estimate of the infested area that is susceptible to gypsy moth defoliation. Basal area was estimated from data collected by the Forest Service's Forest Inventory and Analysis (FIA) Project. These spread models were used to generate the expected extent and area of the generally infested area and transition zone in 2010.

Predicting Defoliation

Because detailed forest composition maps are not available for all portions of the United States, forests that are susceptible to defoliation by the gypsy moth were mapped at the county level. First, FIA data from several thousand plots were used to calculate the proportion of each county in the United States that is covered by susceptible forests. A susceptible forest was defined as one where the gypsy moth may cause visible defoliation. To relate the probability of defoliation to forest composition, a simple model developed by Herrick and Gansner (1986b) was used. In this model, susceptible forests are defined as stands where greater than 20 percent of the basal area is represented by susceptible species. See *appendix D* for a list of susceptible species. Estimates of the proportion of each county that is covered by susceptible forests were combined in a GIS with maps of past and future gypsy moth infested areas. The result was a calculation of past and future susceptible areas. This process is described in more detail elsewhere (Liebhold and others 1993).

On average there is a 5-year lag from the time of first quarantine to the time of first defoliation by the gypsy moth in any county (Liebhold and others 1992). Therefore, a model of yearly defoliation was based on historical defoliation data (USDA Forest Service 1994d). This model predicted defoliation as a function of quarantine of susceptible areas lagged by 5 years:

$$\log(\text{defoliated area}) = -9.60 + 2.15 \log(\text{quarantined areas})$$

Predicting Isolated Infestations

APHIS maintains a database of historical eradication programs conducted to eliminate isolated

Pattern of infestation without eradication

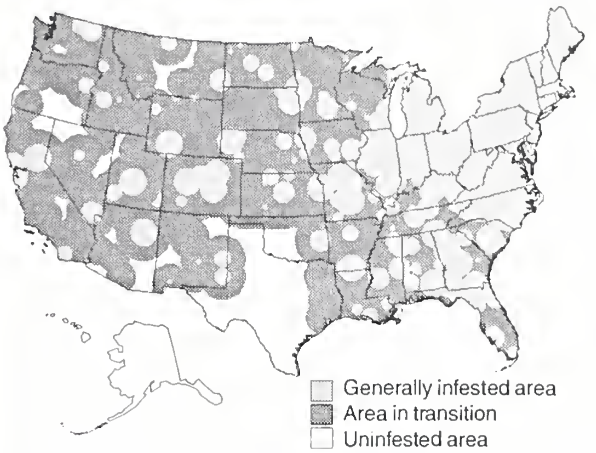


Figure 2-11. Although introductions of the gypsy moth are more likely in certain areas, as described in the section on Where Eradication Would Be Conducted, the actual locations are subject to chance. One of many possibilities is shown here.

infestations of the gypsy moth (USDA APHIS 1994). These historical data were used as the basis for a logistic regression model that predicts the yearly probability of an eradication project (isolated infestation) as a function of four factors—the distance from the generally infested front (DIST), mean human population density in the county (DENSITY), mean per capita income for that county (INCOME), and size of the generally infested area (SIZE):

$$B = -8.76 - 0.00032\ \mathrm{DIST} + 0.00018\ \mathrm{DENSITY} + 0.000323\ \mathrm{INCOME} + 1.42E - 8\ \mathrm{SIZE}.$$

This equation was used to simulate yearly isolated infestations from 1995 to 2010. Without eradication, isolated infestations were assumed to remain restricted to individual 1 km by 1 km areas for 10 years, and then to spread as predicted in the earlier section on Predicting Gypsy Moth Spread. Since the logistic regression model predicts only a probability of an isolated infestation, a Monte-Carlo technique was used to simulate isolated infestations. Simulations for 1995-2010 were run 100 times (*fig. 2-11*). Then for each of these simulations the acreages of the generally infested and transition areas were calculated. The areas given for alternatives 1 and 2 in *table 2-2* and shown in *figure 2-12* thus are means of these 100 simulations.

Table 2-2 lists expected conditions for all of the alternatives by the year 2010, for the generally infested, transition, and uninfested areas.

Figure 2-12 displays the expected conditions for the alternatives by the year 2010. See *figure 1-2* for conditions as they appeared in 1994.

Response to USDA's Program Goal

Alternatives vary in how they respond to the gypsy moth program goal of reducing the adverse effects of the gypsy moth nationwide by protecting forests and trees. Differences occur in how the alternatives prevent or minimize damage to resources, eliminate isolated infestations, and reduce the rate of spread.

Preventing or Minimizing Damage to Resources

Under alternatives 2, 4, and 6, gypsy moth suppression projects could be conducted to reduce gypsy moth populations and to protect foliage in areas where resource values are high. Under alternatives 1, 3, and 5, areas with moderate or heavy gypsy moth outbreaks that are not treated would incur effects due to the gypsy moth. Under all alternatives, in parts of the generally infested area, gypsy moth outbreaks will not occur and defoliation will not be noticeable. Suppression projects usually are not conducted in these areas.

Eliminating Isolated Infestations

Eradication projects are conducted to eliminate isolated infestations of the gypsy moth to prevent their establishment.

Eradication of the Asian and European strains of the gypsy moth would be conducted under alternatives 3, 4, 5, and 6. The potential number of annual eradication projects by the year 2010 would be highest under alternatives 5 and 6. The reason is that the larger size of the uninfested area would provide a greater area where isolated infestations could occur compared with alternatives 3 and 4 (*fig. 2-12*).

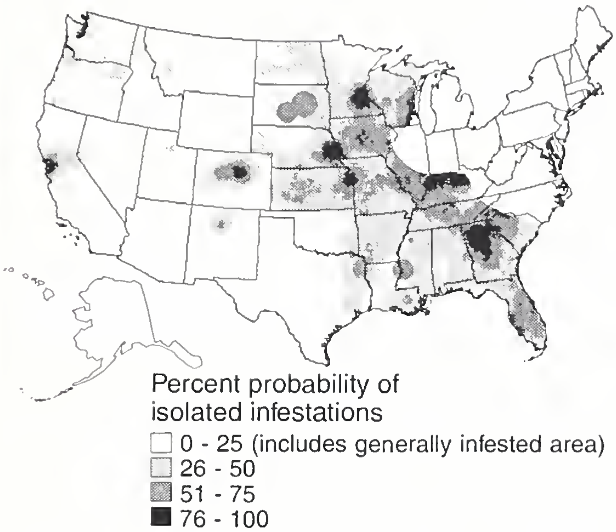
Table 2-2. Estimated conditions by the year 2010, by area and alternative

	Alternative and strategy[1]							
Area, gypsy moth population level, and USDA response	1	2 S	3 E	4 S, E	5 E, STS 75%[2]	 25%[3]	6 S, E, STS 75%[2]	 25%[3]
				Millions of Acres				
Generally Infested Area								
Innocuous populations, no effects	616	616	291	291	196	259	196	259
Gypsy moth outbreaks and defoliation								
No treatment; effects due to gypsy moth	69	57	14	12	8	12	7	10
Insecticide treatment; effects due to insecticides; effects due to gypsy moth reduced	NA[4]	12	NA	2	NA	NA	1	2
Generally infested area total	***685***	***685***	***305***	***305***	***204***	***271***	***204***	***271***
Transition Area								
No detectable populations, no effects	1032	1032	70.5	70.5	51.75	62.70	51.75	62.70
Detectable populations								
No treatment; gypsy moth spreads; effects due to gypsy moth begin to be noticeable	5	5	0.5	0.5	NA	NA	NA	NA
Insecticidal treatment; effects due to insecticides; gypsy moth spread is slowed; effects due to gypsy moth delayed	NA	NA	NA	NA	0.23	0.27	0.23	0.27
Noninsecticidal treatment; gypsy moth spread is slowed; effects due to gypsy moth delayed	NA	NA	NA	NA	0.02	0.03	0.02	0.03
Transition area total	***1037***	***1037***	***71***	***71***	***52***	***63***	***52***	***63***
Uninfested Area								
No gypsy moths present; no effects	541	541	1886.48	1886.48	2006.35	1928.43	2006.35	1928.43
Isolated infestations								
Number of infestations[5]	(76)	(76)	(263)	(263)	(324)	(284)	(324)	(284)
Acres treated	NA	NA	0.52	0.52	0.65	0.57	0.65	0.57
Uninfested area total	***541***	***541***	***1887***	***1887***	***2007***	***1929***	***2007***	***1929***

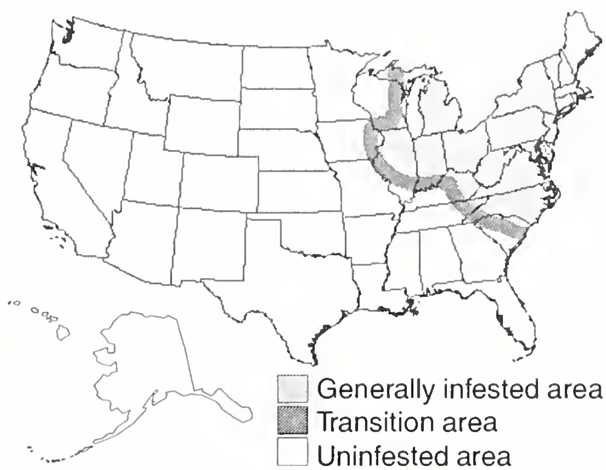
[1]S=suppression, E=eradication, STS=slow the spread
[2]Rate of spread slowed to 3.25 miles per year (5.25 km/yr), or by 75% of historical rate (13 mi or 21 km per year)
[3]Rate of spread slowed to 8.75 miles per year (15.75 km/yr), or by 25% of historical rate (13 mi or 21 km per year)
[4]NA = not applicable.
[5]Number of infestations is given in parentheses.

Estimated conditions in 2010

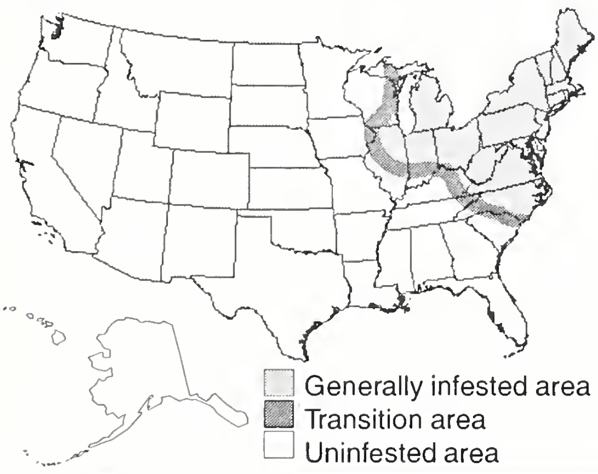
Alternatives 1 and 2



Alternatives 3 and 4



Alternatives 5 and 6
(Spread reduced by 25 percent)



Alternatives 5 and 6
(Spread reduced by 75 percent)

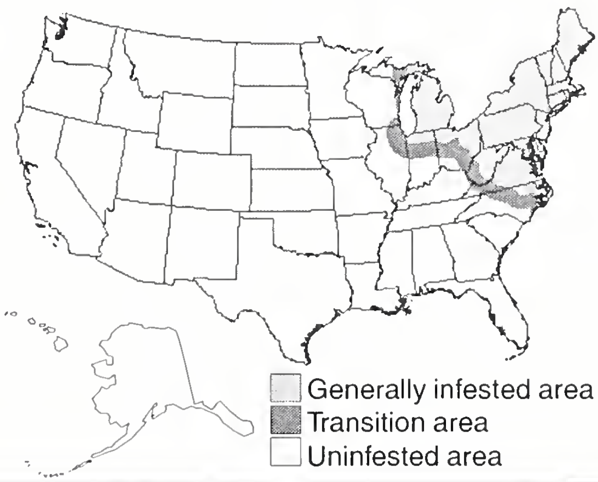


Figure 2-12. In 2010, despite implementation of suppression in alternative 2, isolated infestations will occur and establish without eradication, and the gypsy moth will continue to spread at the current rate under both **alternatives 1 and 2**.

In 2010 conditions would be similar under **alternatives 3 and 4**, despite implementation of suppression in alternative 4. In both alternatives, eradication would eliminate isolated infestations throughout the country, however, gypsy moth will continue to spread at the current rate.

In 2010 conditions would be similar under **alternatives 5 and 6**, despite implementation of suppression in alternative 6. In both alternatives, eradication would eliminate isolated infestations throughout the country, and slow the spread would reduce the rate at which the gypsy moth spreads. The two maps show different rates of gypsy moth spread.

Under alternatives 1 and 2, which exclude eradication, defoliation caused by the gypsy moth would become a problem in new generally infested areas, as isolated infestations become established and begin to grow (*fig. 2-11*). As a result, the gypsy moth would be expected to infest all suitable habitats much sooner than if eradication were to continue.

Introductions of the Asian strain of the gypsy moth are expected to continue under all alternatives. Such introductions could occur anywhere in the United States, but most would probably occur in and around ports of entry (sea or air) that receive cargo from countries where the Asian strain is found.

Reducing the Rate of Spread

Under alternatives 5 and 6 the slow-the-spread strategy could reduce the rate of spread. Under alternatives 1, 2, 3, and 4, which do not include slow the spread, the gypsy moth would spread by natural means, or artificially via movement of infested articles, or both.

Response to Issues

The principal issues identified through public involvement are these:

- How does the presence of the gypsy moth affect people and the environment?
- How do the insecticide treatments applied to the gypsy moth affect people and the environment?
- How do the noninsecticidal treatments applied to the gypsy moth affect people and the environment?

In response to these issues, effects on ecological components of the environment, human health and safety, and social and economic factors were analyzed. The ecological components include nontarget organisms, forest condition, water quality, microclimate, and soil. The social and economic factors include perceptions and behaviors, economics, and recreation.

In *tables 2-3* through *2-8*, the potential for effects due to the gypsy moth and to treatments have been subjectively ranked as follows:

- High—effects are expected frequently,
- Low—effects are expected occasionally,
- Minimal—effects are possible but not expected,
- None—effects are not possible.

Rankings of the potential for effects apply to local areas that could be treated. In some cases a choice of treatments would result in a range of potential effects.

Nontarget Organisms

The degree to which nontarget organisms could be affected under the alternatives depends upon the degree and extent of defoliation, the condition of the species' habitat before defoliation, the type of treatment used, and how it is applied. Heavy defoliation and any subsequent tree mortality alters wildlife habitat in forests by changing vegetation structure, cover, food, and availability of prey. For example, mortality of individual trees benefits some cavity nesting birds by providing dead trees for nesting sites. More extensive tree mortality increases shrubs and herbaceous plants that white-tailed deer eat. Some of the treatments that could be used under the alternatives may indirectly pose a risk to some wildlife species by affecting food supplies. For example, reductions in nontarget moths and butterflies might indirectly affect birds that prey on them.

In general, diflubenzuron will adversely affect more nontarget invertebrate species than *B.t.k.* would. Effects of using diflubenzuron and *B.t.k.* on nontarget organisms could be greater in eradication project areas because two applications of diflubenzuron or two to three applications of *B.t.k.* are used. Mass trapping is not likely to adversely affect nontarget organisms except those invertebrates that enter the traps. The nucleopolyhedrosis virus (Gypchek), mating disruption, and the sterile insect technique are not likely to cause adverse effects on nontarget species.

Alternative 1 would provide the greatest risk of heavy defoliation from the gypsy moth and would be most likely to cause the greatest change to wildlife habitat. Alternative 3 follows closely, and then alternatives 5, 2, and 4. Alternative 6 is least likely to result in a change in habitat due to heavy defoliation.

Alternative 6 has the potential to cause the greatest change to nontarget wildlife species due to treatment, followed by alternatives 4, 2, 5, and 3,

Table 2-3. Potential for changes in nontarget organisms, by area and alternative[1]

Area affected	1	2 S	3 E	4 S,E	5 E,STS	6 S, E, STS
			Alternative and strategy[2]			
Effects due to the gypsy moth						
Infested area	High	Low	High	Low	High	Low
Transition area	Low	Low	Low	Low	Minimal	Minimal
Uninfested area	Low	Low	Minimal	Minimal	Minimal	Minimal
Effects due to treatments						
Infested area	None	None to high	None[3]	None to high	None[3]	None to high
Transition area	None	None	None[3]	None[3]	None to high	None to high
Uninfested area	None	None	None to high	None to high	None to high	None to high

[1]High—effects are expected frequently, low—effects are expected occasionally, minimal—effects are possible but not expected, none—effects are not possible.
[2]S = suppression, E = eradication, STS = slow the spread.
[3]The potential for effects from eradicating the Asian strain of the gypsy moth would be none to high.

because these alternatives provide the greatest opportunity for exposure to diflubenzuron and *B.t.k.* Under alternative 1 no treatment projects would be conducted.

Table 2-3 shows the potential for changes in nontarget organisms by alternative.

Forest Condition

Tree mortality can result from heavy defoliation caused by the gypsy moth. Other effects from heavy defoliation include reduced growth, change in stand structure, reduction in mast production, increase in shrubs and herbaceous plants, increase in the kinds of plants, increases in trees less susceptible to the gypsy moth, and increased fire hazard. The severity of defoliation, the number of successive years of defoliation, the vulnerability of the trees defoliated, and their condition before defoliation are factors that determine the extent of effects due to defoliation. Whether a change in forest condition is adverse or beneficial is a judgment based on the management objectives for the trees, stands, forests, or forest ecosystems being considered. For example, oak mortality could have an adverse effect on squirrels by reducing mast, and a beneficial effect on woodpeckers by increasing nesting and feeding sites.

Table 2-4. Potential for changes in forest condition, by area and alternative[1]

Area affected	Alternative and strategy[2] 1	2 S	3 E	4 S, E	5 E, STS	6 S, E, STS
Effects due to the gypsy moth						
Infested area	High	Low	High	Low	High	Low
Transition area	Low	Low	Low	Low	Minimal	Minimal
Uninfested area	Low	Low	Minimal	Minimal	Minimal	Minimal
Effects due to treatments						
All areas	None	None	None	None	None	None

[1]High—effects are expected frequently, low—effects are expected occasionally, minimal—effects are possible but not expected, none—effects are not possible.
[2]S = suppression, E = eradication, STS = slow the spread.

Alternatives that include suppression prevent or minimize defoliation and are less likely to result in a change in forest condition. No known direct effects on forest condition result from the use of any of the treatments available for use under the alternatives. Therefore, alternative 1, which provides the greatest opportunity for heavy defoliation would be most likely to result in a change in the existing condition of a forest or group of trees. The ranking of the remaining alternatives from most to least likely to result in a change in forest condition is alternatives 3, 5, 2, 4, and 6. *Table 2-4* shows the potential for changes in forest condition by alternative.

Water Quality

The presence of the gypsy moth and defoliation pose greater risks of a change in water quality than do any of the treatments. The severity of the effects depend upon the level of the gypsy moth populations and the extent of the defoliation. Extensive defoliation causes increases in water temperature, nitrate levels, stream flow and yield, acidity levels, and coliform and fecal streptococcal densities. The capacity to neutralize acids and levels of dissolved oxygen decrease.

The potential for a change in water quality due to heavy defoliation is greatest in alternatives that offer the least control of the gypsy moth and defoliation. Alternative 1, which offer no control is most likely to result in changes in water quality, followed closely by alternative 3, then in descending order, alternatives 5, 2, 4, and 6.

Table 2-5. Potential for changes in water quality, by area and alternative[1]

Area affected	Alternative and strategy[2] 1	2 S	3 E	4 S, E	5 E, STS	6 S, E, STS
Effects due to the gypsy moth						
Infested area	High	Low	High	Low	High	Low
Transition area	Low	Low	Low	Low	Minimal	Minimal
Uninfested area	Low	Low	Minimal	Minimal	Minimal	Minimal
Effects due to treatments						
Infested area	None	None to low	None[3]	None to low	None[3]	None to low
Transition area	None	None	None[3]	None[3]	None to low	None to low
Uninfested area	None	None	None to low	None to low	None to low	None to low

[1]High—effects are expected frequently, low—effects are expected occasionally, minimal—effects are possible but not expected, none—effects are not possible.
[2]S = suppression, E = eradication, STS = slow the spread.
[3]The potential for effects from eradicating the Asian strain of the gypsy moth would be none to high.

Short-term changes in water quality due to gypsy moth treatments may occur in some bodies of water. Diflubenzuron that reaches streams could reduce numbers of some aquatic insects and crustaceans, which may cause increases in algae and indirectly affect water quality. Alternative 1 would not result in temporary changes in water quality due to treatments since no treatments would be applied. Alternative 6 would be most likely to result in temporary changes in water quality due to treatments, followed by alternatives 4, 2, 5, and 3. *Table 2-5* shows the potential for changes in water quality by alternative.

Microclimate and Soil

Areas that incur moderate to heavy defoliation have elevated temperatures, reduced humidity, and increased soil moisture. Short-term increases in soil decomposition and mineralization are possible, as well as increases in biological productivity of plants. Changes in microclimate due to treatments are not expected. Although some soil-dwelling and litter-eating invertebrates are at risk from diflubenzuron, soil productivity and fertility appear to be unaffected. Therefore, the potential for change in microclimate and soil is greatest with the least control of the gypsy

Table 2-6. Potential for changes in microclimate and soil, by area and alternative[1]

Area affected	1	2 S	3 E	4 S, E	5 E, STS	6 S, E, STS
			Alternative and strategy[2]			
Effects due to the gypsy moth						
Infested area	High	Low	High	Low	High	Low
Transition area	Low	Low	Low	Low	Minimal	Minimal
Uninfested area	Low	Low	Minimal	Minimal	Minimal	Minimal
Effects due to treatments						
All areas	None	None	None	None	None	None

[1]High—effects are expected frequently, low—effects are expected occasionally, minimal—effects are possible but not expected, none—effects are not possible.
[2]S = suppression, E = eradication, STS = slow the spread.

moth and defoliation. Alternative 1 would be most likely to result in temporary changes in microclimate and soil, followed closely by alternatives 3 and 5. Alternative 6, followed by alternatives 4 and 2 would be less likely to result in temporary changes in microclimate and soil due to the gypsy moth. *Table 2-6* shows the potential for effects on microclimate and soil by alternative.

Human Health and Safety

During gypsy moth outbreaks some people may experience skin irritations caused by an allergic reaction to the hairs on gypsy moths. Eye and respiratory irritations may be possible. These health effects are short-lived and do not pose an imminent hazard or public health concern. On rare occasions outbreaks have been known to result in masses of caterpillars and frass, creating slippery sidewalk and road conditions. Dead trees resulting from repeated defoliation create a potential hazard from falling limbs.

Treatments that use *B.t.k.* may result in minor irritation of the skin, eyes, or respiratory tract in some people if they are directly exposed to the spray. Exposure to Gypchek could conceivably result in irritant effects similar to those from the gypsy moth, because the nucleopolyhedrosis virus formulation contains parts of gypsy moth caterpillars. The likelihood of exposure to the virus formulation is low, however, since it is not widely used. Although diflubenzuron poses no substantial risks to human health, effects on the blood may be detectable at high exposures.

Alternative 1 would provide the most chance for exposure to the gypsy moth and for resulting effects on health, and the least chance for exposure to treatments. In general, alternatives that offer more treatments would result in less opportunity for human interaction with the gypsy moth. Consequently, alternatives 2, 4, and 6 would provide less opportunity for human contact with the gypsy moth

Table 2-7. Potential for effects on human health and safety, by area and alternative[1]

People living in the...	Alternative and strategy[2] 1	2 S	3 E	4 S, E	5 E, STS	6 S, E, STS
Effects due to the gypsy moth						
Infested area	High	Low	High	Low	High	Low
Transition area	Low	Low	Low	Low	Minimal	Minimal
Uninfested area	Low	Low	Minimal	Minimal	Minimal	Minimal
Effects due to treatments						
Infested area	None	None to minimal	None[3]	None to minimal	None[3]	None to minimal
Transition area	None	None	None[3]	None[3]	None to minimal	None to minimal
Uninfested area	None	None	None to minimal	None to minimal	None to minimal	None to minimal

[1]High—effects are expected frequently, low—effects are expected occasionally, minimal—effects are possible but not expected, none—effects are not possible.
[2]S = suppression, E = eradication, STS = slow the spread.
[3]The potential for effects from eradicating the Asian strain of the gypsy moth would be none to high.

than would alternatives 3 and 5. Alternatives 6, 4, and 2 would provide more opportunity for people to be exposed to treatments; alternatives 5 and 3 would provide less opportunity for exposure. *Table 2-7* shows the potential for effects on human health and safety by alternative.

Perceptions and Behaviors

People's attitudes towards the gypsy moth and gypsy moth treatments vary by their familiarity with the insect and with insecticides. People who have experienced outbreaks in the generally infested area feel differently than those who have not. People who have never witnessed a gypsy moth outbreak wonder what the fuss is all about. People who are experiencing a gypsy moth outbreak for the first time may become alarmed and demand something be done about it. People who have experienced several outbreaks over time become accustomed to the events and may be less demanding of government intervention.

Gypsy moth outbreaks can disrupt people's outdoor activities, livelihoods, and plans. Gypsy moth treatments involving aircraft can also disrupt outdoor activities. Some people fear exposure to insecticides. Others experience entomophobia, a fear of insects, in the unavoidable presence of large numbers of caterpillars.

Alternative 1 would provide the greatest opportunity for exposure to the gypsy moth that could influence people's perceptions and behaviors, followed by alternatives 3 and 5. Alternative 2 and then alternative 4 would reduce the chance of exposure to the gypsy moth. Alternative 6 would provide the least opportunity for contact with the gypsy moth that could influence perceptions and behaviors.

Table 2-8. Potential for social and economic effects, by area and alternative[1]
(considers people's perceptions, economics, and recreation)

People living in the...	Alternative and strategy[2] 1	2 S	3 E	4 S, E	5 E, STS	6 S, E, STS
Effects and costs due to the gypsy moth						
Infested area	High	Low	High	Low	High	Low
Transition area	Low	Low	Low	Low	Minimal	Minimal
Uninfested area	Low	Low	Minimal	Minimal	Minimal	Minimal
Effects and costs due to treatments						
Infested area	None	None to high	None[3]	None to high	None[3]	None to high
Transition area	None	None	None[3]	None[3]	None to high	None to high
Uninfested area	None	None	None to high	None to high	None to high	None to high

[1]High—effects are expected frequently, low—effects are expected occasionally, minimal—effects are possible but not expected, none—effects are not possible.
[2]S = suppression, E = eradication, STS = slow the spread.
[3]The potential for effects from eradicating the Asian strain of the gypsy moth would be none to high.

Alternative 6 would provide the greatest chance for people to encounter a gypsy moth treatment that could affect their perceptions and behaviors, followed by alternatives 4 and 2. Alternatives 3 and 5 would provide less chance of encountering a treatment. Perceptions and behaviors would not be affected by treatment under alternative 1. *Table 2-8* shows the potential for effects on social and economic factors, including perceptions and behaviors, by alternative.

Economics

Economic consequences can be immediate, accrue over time, or occur at some time in the future. Direct costs of projects and costs related to the gypsy moth include these: maintenance costs for removing caterpillars or their waste, washing or repainting buildings, removing dead or dying trees, and replacing trees; reductions in property value; increased energy costs for air conditioning; losses in timber value; and losses in recreation and tourism businesses. Gypsy moth outbreaks result in increased demand for gypsy moth control, benefiting some related businesses and contractors. Economic consequences related to the effects of the gypsy moth would be greatest under alternative 1, followed by alternatives 3, 5, 2, 4, and 6.

Suppression provides immediate relief from some economic consequences associated with the gypsy moth. Eradication postpones indefinitely the need for suppression. Slow the spread may delay it for several years.

Costs are associated with planning and conducting gypsy moth treatment projects. Costs associated with treatments would be greatest under alternative 6, followed by alternatives 4, 2, 5, and 3. There would be no treatment costs under alternative 1. With no USDA assistance, other Federal and State agencies would incur the full cost of gypsy moth control projects if they chose to conduct them. Companies and employees who contract with

Table 2-9. Flexibility in managing ecosystems, by area and alternative[1]

Area affected	Alternative and strategy[2] 1	2 S	3 E	4 S, E	5 E, STS	6 S, E, STS
Infested area	Low	High	Low	High	Low	High
Transition area	Low	Low	Low	Low	High	High
Uninfested area	Low	Low	High	High	High	High

[1]Low—technical support only, high—technical and financial support, and participation in activities.
[2]S = suppression, E = eradication, STS = slow the spread.

Federal and State agencies to treat the gypsy moth through cooperative projects could be adversely affected. Regulatory activities, such as restrictions on interstate commerce and international trade with Mexico and Canada, could increase to avert uncontrolled spread of the gypsy moth. *Table 2-8* shows the potential for costs relating to the gypsy moth and treatments, by alternative.

Recreation

Recreational opportunities and enjoyment can be affected by the presence of the gypsy moth, defoliation, and the application of insecticides. The degree to which recreational activities are affected is a result of gypsy moth population levels, whether they are prevented from reaching outbreak levels, and the chance of encountering gypsy moth treatments.

Recreational activities would least likely be disrupted by gypsy moth outbreaks in situations where the greatest control of gypsy moth is provided—in alternative 6, followed by alternatives 4, 2, 5, then 3. Alternative 1, which offers no gypsy moth treatment, would result in the greatest disruption of recreational activities by the gypsy moth. Disruption of recreational activities or changes in recreation use to avoid areas treated with insecticides would be greatest under alternative 6, followed by alternatives 4, 2, 5, then 3, with no effects under alternative 1. *Table 2-8* shows the potential for effects on recreation due to the gypsy moth and treatments, by alternative.

Flexibility to Manage Ecosystems

The alternatives differ in the strategies they offer and the options that the USDA may exercise in managing ecosystems or in helping others to manage ecosystems. Alternative 6 would offer the most strategies and provide land managers with the greatest range of options and, therefore, the most flexibility in managing ecosystems where the gypsy moth is a consideration. Alternative 6 would allow for—but not require—cooperative gypsy moth projects anywhere in the United States where the insect may be found.

In descending order, alternatives 4 and 5, then 2 and 3 would provide managers with less flexibility. Alternative 1 would provide managers with the least amount of flexibility because it excludes the option of managing the gypsy moth. *Table 2-9* shows the degree of flexibility based on the number of options available to manage ecosystems, by alternative.

Standard Operational Procedures and Mitigating Measures

Standard Operational Procedures

Standard operational procedures are routine procedures for conducting gypsy moth control

activities. These procedures safeguard project personnel, the public, and the environment. Standard operational procedures for gypsy moth projects are outlined in Forest Service and APHIS program documents, which serve as reference material for project managers. Two examples are the APHIS Gypsy Moth Program Manual (USDA APHIS 1990) and Cooperative Suppression and Eradication Projects: Guidelines for Participating State Agencies (USDA Forest Service 1994d). While documents such as these provide overall guidance, project specific operational procedures need to be developed and included in project environmental analyses, project work plans, and safety plans.

In 1993 the U.S. EPA published the final rule on the Worker Protection Standard (WPS). WPS regulations are designed to further minimize the exposure of agricultural workers to pesticides, and require that U.S. EPA approved pesticide labels carry standard WPS language that details, among other requirements, how soon after treatment workers can reenter treated areas. The WPS regulations, however, provide an exemption to these rules for ". . . government sponsored wide area public pest control programs . . ." (U.S. EPA 1993, p. 17), such as cooperative gypsy moth projects. The current labels for the insecticides used in gypsy moth projects state that exemption, so workers may reenter project areas immediately after treatment.

By law, Federal agencies must comply with the Endangered Species Act. The following standard operational procedure applies to all gypsy moth control projects that are conducted in cooperation with the USDA, and will be followed during site-specific environmental analysis: consultation (formal or informal) with the U.S. Fish and Wildlife Service, or where appropriate the U.S. Department of Commerce, National Marine Fisheries Service, will ensure that gypsy moth treatments do not jeopardize the continued existence of any Federally listed or proposed endangered or threatened plant or animal species, to the loss of viability, or contribute to trends towards listing of any plant or animal. If endangered, threatened, or proposed species are present in a project area, protection measures will be established to conserve populations and habitat.

Mitigating Measures

Mitigating measures are designed to reduce adverse environmental effects that might result from conducting a treatment project. Mitigating measures tend to be site-specific, that is, they are designed considering the unique characteristics of the project area and addressing local needs and concerns. Several approaches to mitigation may be taken:

- Avoid effects altogether by not taking a certain action
- Minimize effects by limiting the degree or magnitude of an action and its implementation
- Rectify an effect by repairing, rehabilitating, or restoring the affected environment
- Compensate for the effect by replacing or providing substitute resources or environments.

Implementing each of the alternatives would cause environmental effects. Some of these effects would be adverse and would require development of mitigation measures. The use of insecticides is a major component of the strategies in the preferred alternative, which authorizes a program consisting of suppression, eradication, and slow the spread. Depending on the insecticide used there could be a range of environmental effects, both beneficial and adverse, that would need to be weighed and balanced for each project. For example, the use of a particular insecticide may rid residential areas of the adverse effects of the gypsy moth—defoliation, nuisance, and skin rashes; however, the tradeoff may be increased concern about exposure to insecticides, general anxiety, and effects on nontarget organisms.

Before treatment projects could be conducted, site-specific environmental analyses required by the National Environmental Policy Act would be conducted. Development of mitigating measures is part of these analyses, after consideration of site-specific issues and unique characteristics of project areas.

The mitigating measures that follow address the general adverse effects that could result from implementing the preferred alternative. These effects are described in *chapter 4*.

Adverse Effects on Nontarget Organisms

After exposure to *B.t.k.* some nontarget moth and butterfly caterpillars may be adversely affected, in addition to gypsy moth caterpillars. After exposure to

diflubenzuron, moth and butterfly caterpillars, grasshoppers, parasitic wasps, some beetles, sawflies, juice-feeding insects, spiders, benthic crustaceans, aquatic insects, and immature planktonic crustaceans may be directly affected. Parasites that use these moths and caterpillars as hosts may be indirectly affected. Predators, including some birds and bats that feed on lepidopterans, also may be indirectly affected.

Mitigating measures for nontarget organisms include these:

- Use public involvement to identify any site-specific issues on effects on nontarget organisms, and to design appropriate means to mitigate these effects.
- Choose a treatment taking into consideration maximizing project efficiency, potential effects on nontarget organisms, and the potential for nontarget organisms to recolonize areas if they are displaced or die after treatment.
- Establish buffer zones to minimize or eliminate insecticide drift to areas of special concern, such as wilderness or sensitive species habitat.
- Review maps and conduct ground inspections or other actions as part of the site-specific analyses, to identify small brooks, wetlands, estuarine waters, bat caves, or other sensitive areas, and to determine actions needed to minimize adverse impacts.

Adverse Effects on Water Quality

Water quality may be indirectly affected after treatment with diflubenzuron in the form of temporary increases in algae due to a reduction of aquatic invertebrates that feed on algae.

Mitigating measures for water quality include these:

- Establish buffer zones around water, or use alternative treatments.
- Mix, load, and unload insecticides in areas where an accidental spill would not contaminate bodies of water.

Adverse Effects on Human Health and Safety

When people are directly exposed to *B.t.k.* and Gypchek, some may develop minor irritation of the skin, eyes, or respiratory tract. Exposure to high levels of diflubenzuron may cause detectable but insignificant increases in methemoglobin, a form of hemoglobin in the blood that is incapable of carrying oxygen. Gross mishandling or tampering of gypsy moth traps that contain the insecticide dichlorvos can result in human health effects of concern. Individuals exposed to disparlure used in mating disruption and mass trapping may attract adult male gypsy moths for a considerable period of time, which can be a nuisance.

Mitigating measures for human health and safety include these:

- Have workers who handle insecticides wear appropriate personal protective gear and protective clothing.
- Give project workers a copy of the project safety plan and safety briefings.
- Do not employ workers known to be sensitive to insecticides in a capacity that increases risk of exposure to insecticides.

Balloons may be used to mark locations where sensitive species exist and that are off-limits to treatment.

- Have workers who handle the dichlorvos insecticide strips wear gloves and assemble the gypsy moth traps outdoors, preferably at the trap site.
- When possible, in residential areas use gypsy moth traps that do not contain dichlorvos.
- Use public involvement to identify human health and safety issues, including the concerns of people who are sensitive to insecticides. Public notification is an important part of the program so that people living in treatment areas can plan their activities to avoid exposure.
- Consider social and cultural factors. If minority or low income populations are identified in the project area, take steps necessary to ensure that these populations understand the project and are invited to participate and provide input during its development. For example, in some areas public notices and information pamphlets may be translated to other languages.
- Notify hospitals, schools, public health facilities, and local law enforcement agencies of insecticide treatments, the types of insecticides used, and risks to humans.
- Give notification of insecticide treatment projects to organizations, groups, and agencies that consist of or work with people who are chemically sensitive or immunocompromised.

Adverse Effects on Perceptions and Behaviors

Disturbance from some gypsy moth treatments, such as that from low-flying aircraft, may disrupt people's activities while treatments are in progress. Some people fear exposure to insecticide treatments.

Mitigating measures for perceptions and behaviors include these:

- Notify the public about planned treatments, including the insecticides to be used, their potential health effects, and other characteristics of the project, such as low-flying aircraft.
- Notify people living in the project area of impending treatments sufficiently in advance so that they can plan their activities and avoid exposure.

Adverse Economic Effects

Organic farmers will not be able to certify and market their crops as chemical free if they are exposed to diflubenzuron.

Mitigating measures for economic effects include these:

- Tailor public involvement to reach people with specialized interests, such as organic farmers.
- In areas where organic farming operations are conducted, use treatments other than diflubenzuron if possible.
- Establish untreated buffer zones around organic farming operations to mitigate the potential for drifting insecticides landing in fields.

Adverse Effects on Recreation

Use of recreational areas may temporarily be disrupted when areas are being treated with insecticides. A mitigating measure is posting a notice of proposed treatment in recreation sites. Alternative recreation sites, if available, should be listed.

Chapter 3

Affected Environment

Woodland infested by the gypsy moth, Swampscott, Massachusetts, August 1891

Chapter 3
Affected Environment
Contents

This chapter follows an ecological approach in describing the environment that is affected by the gypsy moth and treatments. To address the issues stated in *chapter 1*, the affected environment was divided into environmental and human factors. These factors are described in this chapter, and how they could be affected by the alternatives is described in *chapter 4*.

Because this is a programmatic document, the description of the affected environment contained in this chapter is national in scope. The environment that would be affected by proposed gypsy moth treatment projects will be considered in site-specific environmental analyses.

Location

The potentially affected environment in the United States is anywhere vegetation susceptible to gypsy moth feeding is found, from coastal zone to mountainous timberline. Variables such as climate affect the successful establishment of the gypsy moth in new areas, but given the known distribution of the gypsy moth worldwide, it is probably capable of surviving anywhere in the United States where suitable host plants are available (McFadden and McManus 1991).

Forests

Thirty-three percent of the total land area of the United States, or 737 million acres (298 million ha), are classified as forest (Powell and others 1993). These forests are widely yet unevenly distributed.

Forest trees grow either in pure stands made up of a single species, or they are found as an aggregation of different species growing in mixed stands. Plant species composition is the most important factor that determines forest susceptibility to the gypsy moth (McFadden and McManus 1991). Hardwood species, particularly oaks, are favored by and most susceptible to the gypsy moth. Therefore, the more hardwoods in the composition of a forest, the more susceptible it is to the gypsy moth.

The term "forest cover type" describes plant species composition and classifies forested areas on the basis of vegetation. For inventory, mapping, and other purposes, the Forest Service classifies forested areas by combining forest cover types into "forest type groups." Although forest cover types are based on and named after the tree species that dominate the stand, other tree species may be associated with the stand. These associated tree species may be susceptible to the gypsy moth. For example, the elm-ash-cottonwood forest type group is named after tree species categorized as resistant or immune to the gypsy moth. Within this group, however, is the sugarberry-American elm-green ash forest type. Major associates within this forest type include nuttall, willow, water, and overcup oaks, which are all susceptible to the gypsy moth.

The distribution of forest type groups dominated by hardwood species across the country affects where the gypsy moth may spread, become established, and cause unacceptable damage. Oak-hickory is the largest and most diverse forest type group dominated by hardwoods, and extends from the Great Plains to the eastern seaboard (*fig. 3-1*). The next largest group is the maple-beech-birch type in the Northeastern and Lake States. Oak-pine types are found in the South.

Oak-gum-cypress types are bottomland forests typically found in the South and Southeast, especially within the Mississippi Delta and Piedmont. Aspen-birch forests are located in the North Central States. The smallest forest type group is the elm-ash-cottonwood group, found primarily in bottomlands or wetlands in the Midwest and along the upper Mississippi and Missouri rivers.

In the West, the distribution of hardwood forest type groups is not as clear as in the East. Inventory analysis and type group maps treat the "western hardwoods" as a group in itself, scattered over a large area. Much of south-central and southeastern

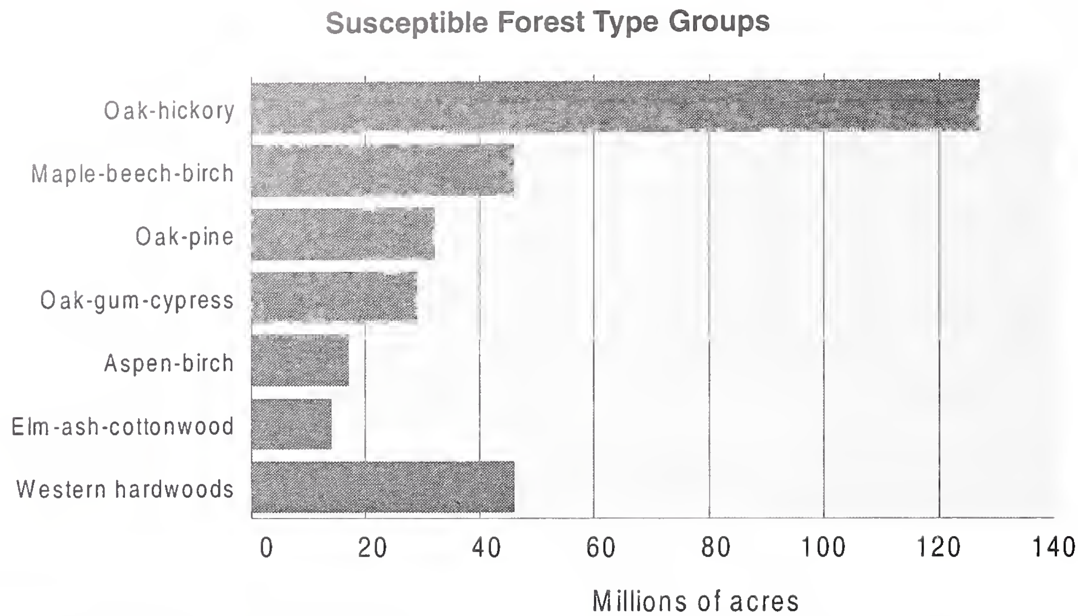


Figure 3-1. Oak species are favored by gypsy moth caterpillars; however, many other hardwood species across the country are also susceptible to gypsy moth feeding.

Alaska have climate suitable for the gypsy moth, susceptible forests of paper birch, and riparian areas with susceptible willow and alder. In the intermountain areas, aspen types are the most abundant hardwood of the group. Oak types predominate in California, while red alder predominates in the Pacific Northwest.

Because the Asian strain of the gypsy moth will likely be a more voracious feeder and thrive better on plants less preferred by the European strain (USDA 1992), introduction of the Asian strain of the gypsy moth has expanded what is considered to be the susceptible forest type groups in this country. The Asian strain is known to feed on larch and tamarack (*Larix* spp.) in Siberia, eastern Asia, and Japan (USDA 1992). Western larch (*L. occidentalis* Nutt.) covers large areas in the northern Rocky Mountains west of the Continental Divide and in the Blue Mountains of northeastern Oregon, and is commonly found in Alaska, northern Washington, Idaho, and western Montana (Eyre 1980). Eastern larch, also called tamarack (*L. laricina* [DuRoi] K. Koch), is scattered in the East.

Douglas-fir dominates the forests of northern California, western Oregon and Washington, and is found scattered in other western States. Douglas-fir in mixture with preferred tree species such as oak, larch, poplar, and alder may be affected if Asian strain populations become established (USDA 1992). If Douglas-fir and other conifers prove to be susceptible, there is an almost unbroken food source for the Asian strain from the Great Plains to the West Coast and north through Alaska (USDA 1992).

Other Areas With Trees

The geographic location of the forest type groups that are susceptible to the gypsy moth are only part of the picture in determining the potential for damage, the potential for spread, and the potential for isolated infestations to become established. Trees that are susceptible to gypsy moth damage grow throughout the United States in residential areas, urban forest areas, community parks, riparian areas, small woodlots, and other areas. These "unforested" areas where people live, work, and recreate also support the establishment and expansion of gypsy moth populations (McFadden and McManus 1991).

Residential areas often include the remains of forests, with tree species such as oaks, aspen, and

Residential areas often have trees susceptible to gypsy moth feeding.

ornamental fruit trees, which are preferred hosts for the gypsy moth. Most suppression and eradication projects have been conducted in these areas.

Many tree species have been studied in the field or the laboratory to determine the gypsy moth's preference for them (Liebhold and others 1995). *Appendix D* (Plant List) gives the susceptibility of over 700 plant species to feeding by the gypsy moth.

Ecological Approach

The potentially affected environment can be described as an ecological continuum (*fig. 3-2*). It varies by the relative physical and biological resources (environmental factors), and amounts of development and natural forest, social and economic resources (human factors). Along the ecological continuum, different types and amounts of food for the gypsy moth are found.

Developed areas have paved roads, sidewalks, and buildings, and generally have more impervious (waterproof) surfaces than undeveloped areas do. Impervious surfaces affect water, soil, and the fate and transport of the insecticide diflubenzuron used in gypsy moth treatment projects. The density of buildings is greatest in the business district of a metropolitan area and decreases with distance from the city center, forming a continuum through city residences and suburbs, to relatively undisturbed natural forests and wilderness. Greenways, parks, wildlife reserves, and agricultural land can interrupt the gradient (Peterson 1982). Residential forest areas contain single and multiple family dwellings, parks, cemeteries, schools, churches, and small businesses.

Environmental Factors

Environmental factors that are affected by the gypsy moth and treatments are nontarget organisms, including endangered and threatened species; forest condition; water quality; microclimate; and soil.

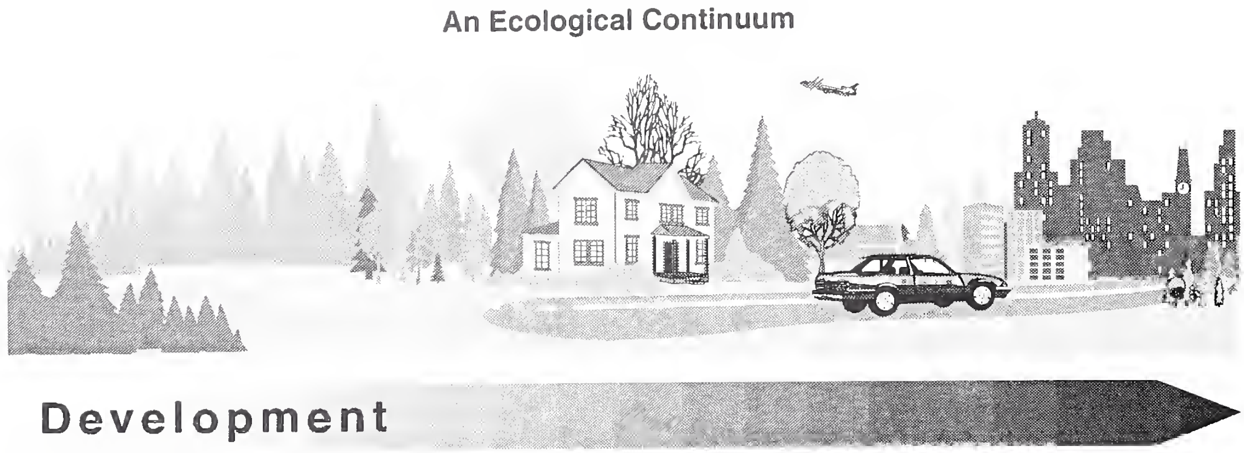


Figure 3-2. Plants susceptible to gypsy moth feeding may be found at any point along the ecological continuum between natural forest and urban areas.

Nontarget Organisms

Virtually all wildlife in the United States that require trees to be part of their environment could be in the potential range of the gypsy moth. Animals from bears to shrews, herons to hummingbirds, salmon, brook trout, butterflies, moths, snakes, salamanders, and snails all have the potential to be found in environments that could be affected by the gypsy moth or gypsy moth treatments.

The variety of species and abundance of wildlife change along the ecological continuum. In general, animal diversity is lower in developed areas than in undeveloped areas. Native animal communities in developed areas tend to be fragmented and small. Animals that do well in urban or fringe areas generally reproduce rapidly and have flexible behavior patterns that enable them to exploit diverse food sources (Gill and Bonnet 1973). In urban areas, species that have adapted to high human population densities (birds such as starling, robin, and crow; and rodents) are often found in high numbers. Domestic animals and pets also make up some of the animal life where there are high concentrations of people. By contrast, forested areas sustain populations of birds, such as warblers, vireos, thrushes, flycatchers, and raptors; bobcat and other predators; large and small mammals; and insects that thrive on native vegetation.

Life under water is another part of the affected environment.

Opossum, skunk, raccoon, and squirrel do well in developed as well as in undeveloped areas. Larger mammals such as fox and coyote can maintain populations in some urban settings. White-tailed deer, common to many undeveloped areas, may be found closer to the developed end of the ecological continuum in areas that have sufficient green space for cover. Larger mammals—such as bear, moose, and wolf—that are sensitive to human disturbances and require greater home ranges tend to inhabit undeveloped regions.

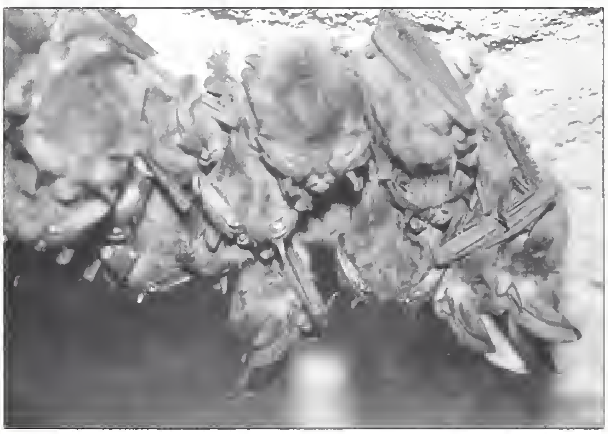
The diversity of birds is lower in urban settings than it is in the undeveloped end of the ecological continuum (Gill and Bonnett 1973). Most bird species in urban areas are year-round residents or

Forest wildlife species, such as wild turkey, are affected by changes in forest condition.

short-distance migrants rather than neotropical migrants, which are more common to undeveloped areas.

Reptiles and amphibians do not fare well in developed areas where native vegetation, breeding sites, and cover have been disturbed. Loss of habitat, travel barriers, and pollution are reasons for fewer numbers of reptiles and amphibians in developed areas than are found in more natural areas (Campbell 1974).

The variety of insect species changes across the ecological continuum. Insects that require habitats



Food supplies for wildlife that eat flying insects are affected by gypsy moth feeding and gypsy moth treatments. (Photo by Craig Stihler, West Virginia Department of Natural Resources)

composed of native plant species tend to be less common in developed areas where people change plant species composition by planting ornamental trees and shrubs.

Introduced and native fish may be found throughout the ecological continuum. Aquatic fauna characteristic of developed areas are generally much less diverse and differ in species and population from aquatic fauna typical of less disturbed habitats.

Endangered and threatened species and their habitats may be found at any point along the ecological continuum. The Endangered Species Act of 1973, as amended, requires the protection of listed endangered and threatened species (50 CFR 17.11, 17.12), proposed species (Federal Register Notice of Review, for 50 CFR Part 17), and their critical habitats.

Any species listed or proposed for listing found in or near forested habitats could potentially be affected by the gypsy moth or gypsy moth treatments. Standard operational procedures for treating areas with Federally listed or proposed species are described in *chapter 2*. Because of their habitat requirements, bats, squirrels, birds of prey, insect-eating birds, snails, insects, crustaceans, and plants are of particular concern.

Forest Condition

Indicators of forest condition include tree mortality rates, tree growth rates, the degree of insect damage, and species composition in the understory and in the canopy. Undeveloped areas are usually characterized by three layers of subcanopy vegetation (trees, shrubs, and ground layer vegetation), as well as leaf litter. Subcanopy trees and shrubs are more sparse in developed areas, and the ground layer of vegetation is often more dense, especially when areas are covered in lawns. The subcanopy and leaf litter are often disturbed and may be absent altogether. Natural plant communities in developed areas tend to be fragmented and small. Native plants often have been replaced with nonnative species. The number of species of aquatic flora is also much lower in developed areas.

The gypsy moth is not the only pest that affects hardwood resources and is changing the nation's forests. Chestnut blight, Dutch elm disease, and—

more recently—beech bark disease, dogwood anthracnose, and butternut canker threaten both natural and urban forests. None of these, including the gypsy moth, poses a uniform threat to any forest. Their potential for impact is great, however, on individual tree species (USDA Forest Service 1993b). As the gypsy moth and other introduced insects and diseases spread, they add additional stress to forest areas. This stress may be responsible, in part, for documented cases of widespread mortality where no single agent appears to be responsible (Weiss and Rizzo 1987).

Water Quality

In areas with plants susceptible to feeding by gypsy moth caterpillars, lakes, streams, rivers, and other surface waters may be part of the affected environment. Indicators of water quality are water temperature, nutrient concentrations, acidity levels, flow rate, and water chemistry. In developed areas, impervious surfaces promote runoff during and after storms. In aquatic habitats in developed areas, the flow rate, peak flow levels, and pollutant and debris levels are substantially greater than those in undeveloped areas.

Microclimate

Across the United States unique sites, such as barrens, bogs, seeps, and caves, have microclimates limited to their physical boundaries. Microclimates created by moisture and temperature conditions found in forests vary by the amount of annual precipitation, elevation, and forest type group. In areas where trees are susceptible to gypsy moth feeding, microclimates potentially are affected.

Soil

All soil types capable of supporting vegetation susceptible to gypsy moth feeding have the potential to be part of the affected environment. Soil supports a great diversity of organisms, such as earthworms, arthropods, and microorganisms that may live in the surface layer, beneath leaf litter, or throughout several soil layers. Many insects spend portions of their life cycle as larvae or pupae in soil.

Soil structural differences support a wide range of soil-dependent organisms across the ecological continuum. For example, ground dwelling arthropods in urban settings are less diverse than those usually found in undeveloped areas (Gilbert 1989). In developed areas, impervious surfaces prevent air and water from penetrating the soil, and soils are often more disturbed and compacted than in undeveloped areas. Impervious surfaces and disturbed soils contribute to a general reduction of plant vigor, root penetration, nitrogen fixation by legumes, and fewer invertebrates to consume and recycle organic matter.

Human Factors

Human factors that are sensitive to the gypsy moth and treatments are human health and safety; perceptions and behaviors; economic characteristics; and recreation.

Human Health and Safety

The health and safety of people in the United States is influenced by many factors, including diet, climate, air-borne diseases, contaminants in soil and water, cultural traditions, emotional well-being, income, and access to medical facilities. People who live in or near areas with trees could be exposed to the gypsy moth and treatments. Included are people with allergic reactions, respiratory ailments, or chemical sensitivities; immunocompromised individuals; pregnant women; homeless people; children; and the elderly. Other people who work in the woods or with trees, mix or apply insecticides, or work in laboratories with the gypsy moth could have frequent exposure to the gypsy moth and treatments.

Social and Economic Factors

Perceptions and Behaviors

Perceptions and behaviors of individuals vary by their familiarity with the presence of gypsy moth

caterpillars and the use of treatments. Reactions to the gypsy moth usually are strongest where outbreaks occur for the first time. In these areas, people become alarmed when huge numbers of gypsy moth caterpillars suddenly appear. In the Northeastern States where the gypsy moth has been present for many years and several outbreaks have occurred, alarm has changed to recognition of the insect as another pest to be dealt with when outbreaks occur.

People's perceptions and behaviors in response to the presence of gypsy moth caterpillars and gypsy moth treatment projects may also vary depending on where people live. In 1990, 187 million people lived in urban areas and 62 million in rural areas across the United States (USDC 1993).

In general, people who live in urban and developed areas spend most of their time in indoor activities, at work, school, or at home. Properties associated with residences, businesses, and municipalities in urban areas typically are smaller than those in rural areas. In urban areas there are fewer host plants to sustain large gypsy moth populations, and people who spend more time indoors are less likely to be exposed to the caterpillars.

Large numbers of gypsy moth caterpillars suddenly appear during outbreaks.

Some undeveloped areas are important to urban residents because they recreate there or visit for a change of pace. Some people who seldom visit undeveloped areas have an interest in these areas, as demonstrated by increased public interest in natural environmental issues. For example, some people who support the preservation of wilderness and endangered species have never seen them.

People in suburban and rural areas are more likely to encounter and be alarmed by large populations of gypsy moth caterpillars. In general, people in rural agricultural areas are less likely to be concerned about spraying to control gypsy moth populations because of their familiarity with spraying of agricultural crops.

Economic Factors

In urban settings, the economy generally is dependent upon manufacturing, construction, wholesale and retail trade, government, transportation, public utilities, finance, real estate, insurance, and service industries. Moving along the ecological continuum towards undeveloped areas, the economy changes to agriculture, mining, fishing, forest product industries, and service industries, particularly those relating to recreation and tourism. Property owners have investments in homes, small businesses, and forest lands that may be affected by the gypsy moth or gypsy moth treatments.

A greater proportion of people whose livelihood is tied directly to natural resources, such as farming, logging, and mining, live in undeveloped areas. Evidence of natural resources management is often visible and generally accepted as a normal occurrence. Some people's livelihoods in undeveloped areas depend on recreation and tourism, which could be negatively affected by the presence of large numbers of gypsy moth caterpillars. In undeveloped areas a greater portion of people's time may be spent outdoors. Here, too, property values are important. Properties generally are larger than in urban areas and, in some cases, are valued for recreational, agricultural, or industrial uses. Undeveloped areas managed by individuals, businesses, and public agencies typically are larger than those found closer to developed areas.

Recreation

Recreation areas are characterized by the physical and biological setting, social environment, and management emphasis. Recreation areas are located in developed and undeveloped areas throughout the ecological continuum, and may be subject to gypsy moth outbreaks and treatments.

Recreational sites typical of urban and suburban areas include parks and zoos; playing fields; picnic areas; nature, hiking, and fitness trails; ponds; streams; and reservoirs. These sites generally get heavy visitor use, although visits tend to be brief or for a day.

The gypsy moth affects areas where people go to enjoy nature.

Recreational sites typical of rural settings are municipal, county and State parks, National Parks and Monuments, National Forests and Grasslands, public and private campgrounds, hiking trails, winter sports complexes, vacation cabins, forest lands used for backpacking, and lakes and rivers used for hunting, fishing, and boating. Rural roads and scenic vistas create a sense of tranquility that draws people to them. Many of the visitors to these areas are tourists who live in more heavily developed areas. Recreational use is generally dispersed over a wide area, and users often stay for longer than a day.

Areas with special values also may be affected by the presence of the gypsy moth or the use of treatments, if treatments are compatible with management direction for the area. Management emphasis varies, but often recreation is an important consideration. These special areas are often associated with the undeveloped end of the ecological continuum (USDA Forest Service 1994b,c). Some examples are wilderness within the National Wilderness Preservation System, rivers within the National Wild and Scenic Rivers System, national wildlife refuges, and experimental forests and ranges. At least 36 million acres are put aside in these and other special value areas in the United States (Powell and others 1993).

Management objectives and administrative regulations and guidelines for these special areas are too diverse to be examined in this environmental impact statement. Decisions relating to gypsy moth management for these areas will be examined on a site-by-site basis, in environmental analyses conducted in accordance with the National Environmental Policy Act and agency procedures.

Chapter 4

Environmental Consequences

Cutting and burning infested woods, Woburn, Massachusetts, December 1895

Chapter 4
Environmental Consequences
Contents

Chapter Overview

The environmental consequences in this chapter are presented in three parts. *Part A* is an examination of effects on human health and safety due to the gypsy moth and treatments that are available to manage gypsy moth populations. *Part B* is an examination of ecological effects. *Part C* is an examination of the environmental effects of the proposed alternatives on a national scale, in terms of the following: effects examined in *parts A* and *B*, response to the three principal issues stated in *chapter 1*, how the alternativies reduce adverse effects of the gypsy moth by protecting forests and trees nationwide, the flexibility each alternative affords resource managers, and projected conditions by the year 2010. This information is provided for decisionmakers to use in making a reasoned choice among the alternatives.

Treatments Examined

The treatments examined in *parts A* and *B* are those available for use in gypsy moth suppression, eradication, or slow-the-spread projects:

- ***Bacillus thuringiensis* var. *kurstaki* (*B.t.k.*)**—a microbial insecticide used in suppression, eradication, and slow-the-spread projects
- **Diflubenzuron**—a chemical insecticide that acts as an insect growth regulator, used in suppression, eradication, and slow-the-spread projects.
- **Gypsy moth nucleopolyhedrosis virus (Gypchek)**—the gypsy moth virus prepared as a microbial insecticide called Gypchek and used in suppression, eradication, and slow-the-spread projects.
- **Mass trapping**—involves the manual assembly and deployment of gypsy moth traps baited with the gypsy moth sex pheromone, disparlure, which attracts male moths to the traps. The delta trap is coated on the inside with a sticky substance, and the milk carton trap contains a plastic strip impregnated with an organophosphate insecticide (dichlorvos). This treatment may be used in eradication and slow-the-spread projects.
- **Mating disruption**—involves the aerial application of disparlure in tiny (0.1 inch [2.5 mm]) plastic dispensers (such as flakes or beads) that release measured amounts of the pheromone over time, to confuse male moths and make it difficult for them to locate females. This treatment may be used in eradication and slow-the-spread projects.
- **The sterile insect technique**—involves manually releasing sterile or partially sterile life stages (pupae or egg masses), to reduce the chance of fertile gypsy moths mating and producing fertile offspring. This treatment may be used in eradication and slow-the-spread projects.

Background information on each of these treatments, and a discussion of their use and effectiveness are in *appendix A*.

To assist in analyzing the human health and ecological consequences of using these treatments in gypsy moth projects, a Human Health Risk Assessment and an Ecological Risk Assessment were prepared. Traditionally risk assessments have focused on the effects of chemical agents. The human health and ecological risk assessments are unique in that they also contain an examination of the effects of the nonchemical agents, *B.t.k.* and Gypchek, and the gypsy moth itself. Including the microbial insecticides was challenging, as new methods had to be developed for them. Including the gypsy moth in the Ecological Risk Assessment also required developing new methods. The ecological information produced from that assessment was used in comparing the environmental

consequences of gypsy moth outbreaks with the environmental consequences of conducting treatments.

Use of Risk Assessments

A risk assessment provides a logical process for evaluating data and analyzing potential effects. Both the human health and ecological risk assessments took into account the way treatments are used in gypsy moth projects, including how the treatment agents are applied, the amount applied, and the types of areas that receive treatment. The resulting risk information is a reasonably accurate analysis of what could occur and indicates potential effects of actual gypsy moth treatment projects.

Standard steps in the risk assessment process were followed (NRC 1983, U.S. EPA 1992b,c):

- **Hazard identification**—gathers known information on toxicity of the gypsy moth and treatment agents, from laboratory and field studies
- **Exposure assessment**—describes the chances for contact with the gypsy moth, and with treatment agents as they are used in gypsy moth treatment projects
- **Dose-response assessment** (human health risk assessment only)—tells how much exposure to the gypsy moth or treatment agents is needed to produce the response (effect) described in the hazard identification
- **Risk characterization**—combines information from the previous steps to predict the likelihood that certain effects will occur in response to the gypsy moth and to the treatments.

Each step in a risk assessment is accompanied by uncertainties, imposed by limitations either in the available data or in the ability to extrapolate the data to scenarios of concern. Assumptions must be made when uncertainties exist, and must be based on rational and deliberate thought. To compensate for uncertainties, risk assessment results tend to be conservative, which means they are more likely to overestimate risks than to underestimate them.

Compounding conservative assumptions in a risk assessment can lead to unrealistic overestimation of risk. On the other hand, the use of overly liberal assumptions can lead to unrealistic underestimation of risk. To ensure that results of the human health and ecological risk assessments were realistic, they were prepared by experts in the field of risk assessment, who were known to use the best available data to provide the basis for their judgments. The risk assessments also underwent peer review by other recognized experts in risk assessment methods, toxicology, and other fields.

Many uncertainties are inherent in conducting and interpreting risk assessments; however, the data available on the agents covered by the risk assessments are adequate to characterize the relative hazards associated with them. Numerical safety factors are usually included in the calculations, to protect more sensitive individuals and to compensate for missing data and any uncertainties. In addition, it is virtually impossible to precisely calculate an exposure value for every situation that may arise. Therefore, models, equations, and statistical techniques were used to quantify hazard, exposure, and risk for the gypsy moth and treatments. Information on fate of insecticides in the environment was used when estimating environmental exposure.

Numerous equations and calculations of risk, based on methods used by the U.S. Environmental Protection Agency (U.S. EPA), were used in the risk characterizations. When information was insufficient to provide a sound quantified risk characterization, qualitative risk characterizations were done.

The two risk assessments are presented in their entirety as separate volumes appended to this environmental impact statement for examination by interested readers.

Chapter 4, Part A
Effects on Human Health and Safety

Contents

Part A
Effects on Human Health and Safety

This part of *chapter 4* describes the human health effects that are plausible from contact with the gypsy moth and from exposure to treatments that could be applied to control the gypsy moth. Included are the potential effects on gypsy moth project workers, the general public, and groups of people who may be at special or increased risk. The potential high risk group includes those who are sensitive to specific chemicals and those with multiple chemical sensitivity.

This part summarizes the Human Health Risk Assessment. For more information on the methods used and results of the Human Health Risk Assessment, see *appendix F*, which is a separate volume.

Methods

The procedures used to assess the risks to human health were similar to those recommended by the National Research Council of the National Academy of Sciences (NRC 1983).

Hazard Identification

Hazard identification determined whether a particular treatment or the gypsy moth can be associated with adverse health effects and identified the effects that it is likely to induce in those exposed to it. The hazard of each treatment and the gypsy moth was examined by reviewing relevant toxicological and pharmacokinetics data from the published literature, manufacturers' information, specific information from knowledgeable experts in the field, and reliable published anecdotal information on exposed populations. The hazard of inert ingredients or possible contaminants in the insecticides was also considered.

Exposure Assessment

The exposure assessment determined the dose of an agent to which humans may be exposed, including the magnitude, duration, schedule, and route of exposure; the size, nature, and types of the populations exposed; and the uncertainties involved in deriving all estimates (NRC 1983). Three steps are involved in assessing population exposures:

- Describing exposure scenarios,
- Estimating levels in the environmental media, such as soil, air, water, and vegetation, and
- Calculating dose rates.

The exposure scenarios selected were based on how the insecticides are applied and the biological, physical, and toxicological properties of the insecticides, or of the gypsy moth. Depending on the insecticide properties and application method, the following were also considered: oral, dermal, inhalation, or combined exposure to the insecticide or to the gypsy moth; exposure of people living in or visiting treated areas and by gypsy moth project workers; and acute, subchronic, or chronic durations of exposure.

Three types of exposure scenarios were considered: routine, extreme, and accidental. For routine exposure, assumptions were that the recommended application rates are used, that recommended safety precautions are followed, and that the estimated model parameter values, such as food or water consumption rates and skin surface area, are based on the most likely activities and circumstances. For extreme exposures, assumptions were that recommended procedures and precautions are not followed and that exposure parameters were based on different activities and circumstances that increased the estimate of exposure. For accidental exposures, the assumption was some form of equipment failure or gross human error occurred. Not all three scenarios were used for each agent. The decision to use a particular scenario was based on its applicability to the agent being assessed and the need to encompass uncertainties in the exposure.

The Human Health Risk Assessment also considered potential exposed or absorbed doses for individuals of different age groups, that is, adults, young children, toddlers, and infants. Values such as

body weights and food consumption rates were taken from standard sources (U.S. EPA 1988c, 1989b).

Dose-Response Assessment

A dose-response assessment, which is conducted only in connection with human health, is the process of characterizing the relationship between a known dose of an agent and the incidence of an adverse health effect in an exposed population. It involves estimating the incidence and severity of the effect as a function of dose or exposure to the specific agent. It also takes into account the intensity of exposure, the age range during exposure, and other variables that might affect the response, such as sex and lifestyle. Extrapolation from high to low dose and from animals to humans is often required (NRC 1983).

Two general types of dose-response assessments were conducted in the human health risk assessment. For noncarcinogenic (noncancer) effects, most dose-response assessments used an approach that involved a no-observed-adverse-effect level (NOAEL) and an uncertainty factor. Dose-response models were used occasionally to assess risks associated with noncancer effects. For carcinogenic (cancer) effects, a different dose-response model was used to estimate cancer risk.

Quantitative toxicological assessments involve deriving an estimate of the dose level that is unlikely to cause adverse health effects in humans. This dose estimate is called the risk reference value (RRV). It is derived by taking the experimental no effect (or equivalent) dose associated with the most sensitive effect and applying a series of uncertainty factors to adjust for differences between the experimental design and the conditions for which the RRV is being derived.

Risk Characterization

Risk characterization is the process of estimating the incidence of a health effect in a human population under the different conditions of exposure represented in the exposure assessment (NRC 1983). The risk characterization process detailed by the U.S. EPA (1989b) generally was followed. It involved comparing the dose to which humans may be exposed, with the RRV. This comparison produces a hazard quotient, which indicates the level of concern regarding one or more exposure scenarios. Because the RRV represents an exposure that is not expected to cause adverse effects, a hazard quotient of 1 or less would not be cause for concern.

All relevant routes of exposure (mouth, skin, respiratory tract) were considered in deriving a composite hazard quotient. A hazard quotient greater than 1 (dose exceeds the RRV) indicated that an adverse effect might be observed after exposure. In some cases, however, uncertainties associated with the hazard identification and exposure assessment required a qualitative judgment to characterize the risk involved. For example individuals with multiple chemical sensitivity (MCS) may be extremely sensitive to even very low levels of exposure to a variety of agents. For the human health risk assessment neither the qualitative nor quantitative impact of MCS could be assessed. This is the case partly because a single set of criteria for diagnosing MCS has not been adopted. It is plausible that individuals with MCS might be sensitive to the gypsy moth or one or more of the agents used to control the gypsy moth, but the impact cannot be characterized further from the available data.

Cumulative Effects

Some exposures, especially to workers, may last for several days to several months. In addition, some program activities may be repeated more than once during a year or for several consecutive years. Such exposures are referred to as cumulative exposures.

Depending on the specific exposure scenario and the nature of the available data, the consequences of cumulative exposures are assessed in a variety of ways. For carcinogenic effects, total dose is assumed to be related directly to risk. Thus, the consequences of two applications at a given rate would be twice those of a single application.

For toxic effects, concern is triggered by exposures that exceed the RRV. Only a limited amount of most control agents may be applied in a given year. Consequently, most exposure scenarios

assume maximum application rates. If the RRV is not exceeded by multiple applications at maximum rates, it will not be exceeded by multiple applications at lower rates. In addition, cumulative effects for exposures that may last several months, such as to residues of diflubenzuron, are considered by using RRV's appropriate for chronic or lifetime exposure. If the daily exposure level does not exceed the level that would be tolerable for a lifetime, exposure for shorter periods will not present a hazard.

Connected Actions

Some individuals may be exposed to several treatment types, either in their job as applicators or because more than one type of gypsy moth treatment is used in the area where they live. Such exposures are considered connected actions, that is, one or more actions that an individual may take that could affect the individual's risk to the agents used to control the gypsy moth. In addition, all individuals are exposed to a multitude of chemicals and biological organisms every day, in foods, medicines, household products, and other environmental chemicals.

Exposure to multiple chemical or biological agents may lead to interactions that are significantly toxic (Yang 1994). For most of the agents under review, relatively little information pertaining to this issue is available. The information that is available is included in the risk characterization for each agent.

Effects Due to the Gypsy Moth

Hazard Identification

Gypsy moth outbreaks have been associated with adverse human health effects, including skin lesions (Anderson and Furniss 1983, Tuthill and others 1984), eye irritation, and respiratory reactions (Perlman 1965, Shama and others 1982). In addition, an allergy specific to the gypsy moth has been suggested (Beaucher and Farnham 1982). The National Institute of Occupational Safety and Health is studying workers who rear insects, to further characterize the nature of effects on the skin, eyes, and respiratory tract from exposure to insects, including the gypsy moth (Petsonk 1994).

Some people are allergic to gypsy moth hairs.

The gypsy moth may also be a nuisance. Although the nuisance issue may not constitute an easily measured health effect, the available literature suggests that gypsy moth outbreaks may cause marked psychological stress in some individuals (National Gypsy Moth Management Group 1991).

During heavy defoliation water quality may be affected by increased runoff and by direct contamination with frass. While caterpillars were feeding, levels of fecal streptococci in stream water were as high as 25,000/100 mL and levels of fecal coliforms exceeded 90/100 mL (Corbett 1992). No adverse effects on human health have been reported, however, in association with these streams entering water supplies.

Exposure Assessment

Gypsy moth populations can be monitored by estimating the numbers of egg masses, caterpillars, or adults. When gypsy moth population densities are less than 50 egg masses per acre, contacts between caterpillars and people are rare. Gypsy moth populations may exist for several years at a density high enough to create a minor nuisance in wooded communities and to cause partial defoliation. Typical population densities in this case may range from 50 to 500 egg masses per acre.

Once the gypsy moth population increases to a full-scale outbreak, the combination of insect frass and leaf fragments, loss of shade at midsummer, and the large number of caterpillars may become a major nuisance (Williams 1982). The duration of such outbreaks is unpredictable. Typical densities can range from 500 to 5,000 egg masses per acre, although densities higher than 20,000 egg masses per acre are recorded occasionally.

Given this relatively localized variability in insect populations, the potential for human exposure cannot be estimated quantitatively. Epidemiology studies conducted in gypsy moth infested communities suggest that standard measures of exposure intensity might not be meaningful, even if they could be made. The most important factor may be the probability of coming into contact with one or more caterpillars, rather than the number of caterpillars in a population. In this respect patterns of human behavior, such as the amount of time spent outdoors and in activities likely to result in contact with caterpillars, may be more important than measurements of the local gypsy moth population. As the density of the caterpillar population in an area increases, exposure is likely to increase. More precise relationships of gypsy moth population density to human exposure are not possible. Therefore, the next step in the risk assessment process for the gypsy moth was called an exposure-response assessment.

Exposure-Response Assessment

Data from three reports on skin reactions in school children were used to estimate the number of skin reactions during outbreaks (Aber and others 1982, Anderson and Furniss 1983, Tuthill and others 1984). Only one of the studies, however, could be used to construct an exposure-response relationship (Tuthill and others 1984 as supplemented by data from ODell 1994).

Two kinds of exposure-response assessments were possible using the available data. The first approach was based on the standard RRV, that is, an exposure level associated with no adverse effects in an exposed population. The second approach related the gypsy moth population density, using egg masses per acre, to the prevalence of skin reactions. Both types of estimates were based on data from Tuthill and others (1984) with supplemental data from ODell (1994).

For the RRV approach, the NOAEL (the no-observed-adverse-effect level) was considered to be the incidence of skin reactions in a community that had a low exposure, when compared with that of a similar community with high exposure. This value was used for the NOAEL because the incidence of skin responses during the week after emergence of caterpillars was not significantly higher than during the week before emergence. The associated exposure was 32 egg masses per acre. Because sensitive individuals are likely to have been included in the study, no uncertainty factor was applied to the egg mass density. That would make the RRV, when rounded to one significant digit, equal to 30 egg masses per acre.

This quantitative relationship of dermal response to egg mass density is based on a measure of egg masses per acre. The incidence of skin rashes during the week of emergence of caterpillars was corrected for a background rate, since not all rashes reported in the week of emergence should be attributed to gypsy moth exposure. Incidence of rashes from the week before emergence was used as the correction factor because it is more likely to reflect the natural background rate of rashes.

The probability of allergic response after exposure to caterpillars was based on the ratio of skin reaction rates to touching the caterpillars. For the low exposure community the probability was 20 percent, and for the high exposure community the probability was 33 percent (Tuthill and others 1984).

Risk Characterization

Exposure to gypsy moth caterpillars is associated with skin, eye, and respiratory effects in humans. In addition, infestations are often considered to be a nuisance and cause esthetic damage to the environment. These responses to the gypsy moth can lead to stress in some individuals. Skin reactions may be considered the most sensitive of all the health effects, that is, if skin irritation is not observed, other health effects are not likely.

Risk of human exposure to the gypsy moth is associated with the probability of coming into contact with an early instar caterpillar. This probability, in turn, is related to the density of people and gypsy moth caterpillars, as well as to the behavior of the people in the infested area. Limited data suggest that the prevalence of skin reactions is greatest among young children (Tuthill and others 1984). This finding may indicate that children are more sensitive than adults to the effects of exposure, and it may reflect the fact that children spend more time outdoors.

Because gypsy moth caterpillar density and human behavior are related to exposure, two types of probabilities are of concern. The first type of probability is conditional: the chance that an individual will have an adverse response, if they contact a gypsy moth caterpillar. This probability is likely to be related to the sensitivity of the individual and to the amount of contact, that is, how often, how long, and how much. The second type of probability is population risk: for a given level of gypsy moth population, the proportion of the human population likely to be affected.

For the general public, risks were characterized for exposure to four gypsy moth population densities: sparse (1-50 egg masses/acre), moderate (50-500 egg masses/acre), heavy (500-5,000 egg masses/acre), and extreme (20,000 egg masses/acre). In infested areas on the East Coast 100 egg masses per acre or less are common (Reardon and others 1993). Extreme egg mass densities are uncommon and are likely only in localized areas during gypsy moth outbreaks.

Hazard quotients for exposure to the four population densities were all greater than 1, indicating that exposed individuals likely would have some adverse response. Also, the more likely the exposure, the greater was the chance of having a reaction; and, the likelihood of exposure increased with higher gypsy moth densities.

A different risk estimate represented the proportion of workers and similarly exposed individuals who would likely have adverse health effects after a significantly high exposure. These values are highly subjective. An estimate of 25 percent approximates the groups of individuals who developed skin rashes after confirmed contact with the gypsy moth. A lower range of 10 percent approximates the proportion of individuals who had no known prior contact with the gypsy moth but showed skin reactions after contact in a clinical study. An upper range of 100 percent is based on the assumption that all individuals may be sensitized to the gypsy moth after prolonged or repeated exposures, or that at least one component of the response is toxic rather than allergic. In either case, all individuals would be expected to respond with sufficient exposure.

The quality of the data supporting the risk characterization for the gypsy moth is moderate to good, in that a good deal of human data are available (*table 4-1*).

Uncertainties

Characterizing risk to human health from the gypsy moth includes these uncertainties: (1) most of the available studies are not directly applicable in a quantitative risk assessment; (2) the exposure-response assessment is based on one epidemiological study in which only two communities were monitored; (3) egg mass density is the only available measure of exposure on which the risk characterization is based; and (4) as with any exposure-response or dose-response assessment, the selection of a dose-response model is somewhat arbitrary and adds another element of uncertainty.

Cumulative Effects

Two types of cumulative effects were considered in assessing the consequences of exposure to the gypsy moth. During one year, repeated exposures likely will occur for the duration that gypsy moth instars are present. Some individuals will be repeatedly exposed in subsequent years. Cumulative effects from exposure during a single season were essentially addressed by the epidemiology study on which the risk characterization was based (Tuthill and others 1984) because this study monitored effects during the period in which early instars were present. The available data do not permit a definitive assessment of the effects of exposure to the gypsy moth over several seasons. Evidence suggests that one of the mechanisms involved in the skin irritation associated with exposure to gypsy moth caterpillars involves an allergic reaction.

Table 4-1. Quality of the data supporting the Human Health Risk Assessment[1]

Step	Gypsy moth	*B.t.k.*	Diflubenzuron	Gypchek	DDVP[2]	Disparlure
Hazard identification	Good	Good	Good	Moderate	Good	Marginal
Exposure assessment						
Workers	Moderate	Good	Moderate	Inadequate	Good	Marginal
Public	Good	Marginal	Good	Marginal	Good	Moderate
Dose-response assessment	Good	Moderate	Moderate	Inadequate	Moderate	Inadequate
Risk characterization						
Workers	Good	Good	Moderate	Inadequate	Good	Inadequate
Public	Good	Moderate	Good	Inadequate	Good	Inadequate

[1]Good—based on adequate human data.
Moderate—based on animal data, analogous compound, or extrapolation.
Marginal—based on tenuous extrapolation or association.
Inadequate—quantitative assessment not supported, qualitative assessment done.

[2]Quality of data for routine exposure only.

Thus, some individuals may become sensitized to the gypsy moth after repeated exposures over one or more seasons.

Connected Actions

There are no known data that can be used to assess the consequences of connected actions involving the various activities in the gypsy moth program or other common activities. Gypchek (one of the insecticides used to treat the gypsy moth), however, contains gypsy moth parts and may cause irritant effects similar to those caused by gypsy moth caterpillars. Consequently, exposure to both gypsy moth caterpillars and Gypchek could be additive, although there are no data showing that this occurs.

Groups at Special Risk

Young children appear to exhibit more reactions than do adults in response to exposure to gypsy moth caterpillars (Tuthill and others 1984). This finding is clearly demonstrated in one study and suggested by a number of other reports. This sensitivity may be the result of higher exposure because children spend more time outdoors than do most adults.

Contact with the hairs on gypsy moth caterpillars causes skin rashes, especially in children. (Photo by Nate Bacon, photographer)

Effects Due to *Bacillus thuringiensis* var. *kurstaki* (*B.t.k.*)

Hazard Identification

Human exposure to *B.t.k.* provides little cause for concern about health effects. For example, in its review of technical information submitted by manufacturers of *B.t.k.* formulations, the U.S. EPA (1988b) concluded that *B.t.* is not a human pathogen but can cause irritation or inflammation. More recently, the British Columbia Ministry of Health (1992) concluded that *B.t.k.* is specific to lepidopteran caterpillars and does not pose a threat to humans.

Under usual conditions, *B.t.k.* formulations do not pose a substantial risk to workers or the general public. In drawing this conclusion, a clear distinction must be maintained between the microorganism *B.t.k.* and commercial preparations of it. As with any preparation containing microorganisms, potential concerns include pathogenicity, persistence of the microorganism in the human body, the genetic stability of the microorganism in the environment, and the ability of the microbial agent to interact with other microorganisms. As a complex mixture of chemicals, formulations may have toxic properties that are unrelated to the presence of *B.t.k.* For example, the available data regarding human exposure to *B.t.k.* formulations suggest that they cause eye, skin, and respiratory tract irritation. It is not clear, however, that these effects are caused by the microorganisms.

To ensure that no formulations contain pathogenic contaminants, the U.S. EPA (1988a) requires that manufacturers implement quality control measures to detect either contamination with other microorganisms or changes from the characteristics of the parent *B.t.* strain. For example, batches are tested and rejected if potentially hazardous bacteria exceed established levels that have been reviewed and accepted by the U.S. EPA (Overholt 1994).

The significance of inert ingredients in commercial formulations of *B.t.k.* was evaluated. Although the identities and quantities of the inert ingredients cannot be made public (Otvos and Vanderveen 1993), all of the ingredients in *B.t.k.* formulations produced by Novo Nordisk (Foray 48B) and by Abbott Laboratories are on U.S. EPA Lists 3 or 4. Inclusion in List 4 indicates that the inerts are generally recognized as safe, and inclusion in List 3 indicates that there is insufficient information to classify them. Information on the categorization of inert ingredients for other *B.t.k.* formulations was not available.

The most common effects from exposure to *B.t.k.* are eye, skin, and respiratory tract irritation, which have been seen in experimental mammals (U.S. EPA 1988a), and in exposed workers (Cook 1994). Two studies indicate possible systemic effects from exposure to *B.t.k.* (Berg 1990, Holbert 1991); however, the effects have not been demonstrated in other studies, and most data do not support these conclusions.

Exposure Assessment

The aerial and ground methods of spraying *B.t.k.* suggest that the likeliest routes of exposure by the general public are by mouth, skin, and respiratory tract. Accidental exposures through the eyes may occur in workers.

Monitoring data for exposure of workers and the general public to *B.t.k.* from aerial sprays are available (Elliott and others 1986, 1988). Worker exposures to *B.t.k.* concentrations in air were substantially the same for pilots, aerial observers, a safety officer, or a security guard. Exposures for all but one card checker were in the general range of other aerial applicators. The one card checker in question had direct contact with the spray during card retrieval.

Card handlers in another study (Cook 1994) were exposed to about 50 times as much *B.t.k.* as card checkers in the previous study (Elliott and others 1988). The substantial difference in exposure concentrations may be related to work practices,

although the studies used different batches of the *B.t.k.* formulation and different analytical methods to determine concentrations. The levels of viable *B.t.k.* spores in batches from the same manufacturer may vary by a factor of at least 50. Thus, the levels of exposure in these two studies are not directly comparable.

During ground spraying, workers may have been exposed to high levels of *B.t.k.*, with concentrations ranging from 0.2 to 15.8 million colony forming units per cubic meter of air (cfu/m^3) (Cook 1994). The maximum cumulative exposure for these workers was 720 million colony forming units (cfu), and the lowest cumulative exposure for these workers was 5.4 million colony forming units. The applicability of these values to the occupational exposure of other ground workers is questionable. Actual exposures depend on the concentration of *B.t.k.* in the applied solution, the specific application methods, the duration of exposure, and the type of job.

Card handlers or checkers who monitor spray deposit during insecticide application have higher exposures than those who remain outside the treatment area.

Workers may be exposed to high levels of B.t.k. *during ground application.*

Dose-Response Assessment

For workers, skin contact with *B.t.k.* suspended in air is the exposure of primary concern. It is the likeliest exposure for ground workers. Only one study is available from which a dose-response assessment can be made for this scenario (Cook 1994).

Reported responses in exposed workers were characterized as irritation to the skin, eyes, and respiratory tract. Low level cumulative exposure (ranging from 5.4 million to 100 million cfu) resulted in each worker reporting 1.5 symptoms—about twice the response rate in a control group (0.8 symptoms per person). Using this information and standard methods and uncertainty factors to calculate risk reference values, the RRV derived for workers was determined to be 0.2 million colony forming units.

The effects covered by this dose-response assessment are of minor clinical significance. The number of workdays lost by ground workers was no greater than that of the control group (Cook 1994).

No dose-response relationship could be proposed for workers on aerial application projects. In monitoring studies, however, exposure of aerial workers to *B.t.k.* was only slightly higher than that of the general public (Elliott and others 1986, 1988).

Two detailed epidemiology studies were available on exposure of the general public to *B.t.k.* One study in Oregon involved the aerial application of Dipel at a rate of 16 billion international units (BIU) per acre (39.5 BIU/ha) over about a quarter of a million acres with a human population of about 40,000 (Green and others 1990). One study in British Columbia involved the aerial application of Foray 48B at a rate of about 20 BIU/acre (49 BIU/ha) (Noble and others 1992). Neither study detected any adverse effects in the exposed populations. In addition, a surveillance program by a group of family physicians noted no substantial difference in the reports of symptoms that might be associated with *B.t.k.* exposure within and outside the spray areas.

The doses in both of these studies were regarded as no-observable-effect levels (NOEL), since neither study detected any effects in exposed populations. Since both studies covered large numbers of individuals in the general population, an uncertainty factor was not used. The higher NOEL of 20 BIU/acre was taken directly as the RRV for the general public. On the basis of both the available epidemiology studies as well as the long history of use, no hazard has been identified for members of the general public exposed to *B.t.k.* formulations. Some individuals, however, may be very sensitive to some components in these sprays. Such individuals are likely to be considered part of a sensitive subgroup, which may not have been represented in the studies.

Risk Characterization

Since commercial formulations of *B.t.k.* are applied by aerial and ground sprays in populated areas, exposure of both workers and the general public are major concerns. A large and compelling body of human experience as well as many toxicity studies on experimental mammals indicate that neither *B.t.k.* nor its commercial formulations are highly toxic or infectious.

Aerial Sprays

For aerial application crews and the general public, the hazard identification is essentially negative, that is, no adverse effects can be attributed to *B.t.k.* exposures during aerial application. Epidemiology studies indicate that application rates of up to 20 BIU/acre have not been associated with adverse effects in humans; consequently, this value was adopted as the RRV. The hazard quotient is 1 for an exposure to 20 BIU/acre; however, the risks associated with exceeding the RRV cannot be directly characterized. No epidemiology studies have been conducted at the maximum application rate of 40 BIU/acre. Thus, the hazard quotient is 2 for this application rate.

Ground Sprays

Exposure of workers to commercial formulations of *B.t.k.* during ground application is likely to cause transient and relatively minor irritation of the skin and respiratory tract. Dose-response relationships for these effects have been demonstrated (Cook 1994). Hazard quotients ranged from 30 to 3600, depending on the specific exposure levels: low, medium, or high. Hazard quotients greater than 1 do not necessarily indicate severe health effects are anticipated for ground workers. The health effects to ground workers associated with the very large hazard quotients, based on exposures reported (Cook 1994), can be classified as relatively mild and transient. Exposure of the general public to ground sprays is similar to aerial sprays, therefore, the hazard quotients are the same (*fig. 4-1*).

Uncertainties

Uncertainties in the risk characterization for *B.t.k.* include these: (1) the complex and variable nature of *B.t.k.* and its formulations; (2) the toxic agent or agents associated with the irritant effects to the eyes, skin, and respiratory tract have not been clearly identified; (3) the dose-response assessment for ground workers is based on only one formulation of *B.t.k.*; and (4) the most meaningful measure of human exposure to *B.t.k.* formulations cannot be determined. That is, is it more meaningful to look for a threshold level below which no effects occur or to take a more conservative approach and use the cumulative exposure per person? The risk assessment used the more conservative approach.

The inability to identify clearly the ingredient or ingredients in *B.t.k.* formulations associated with potential adverse effects complicates the analysis. In

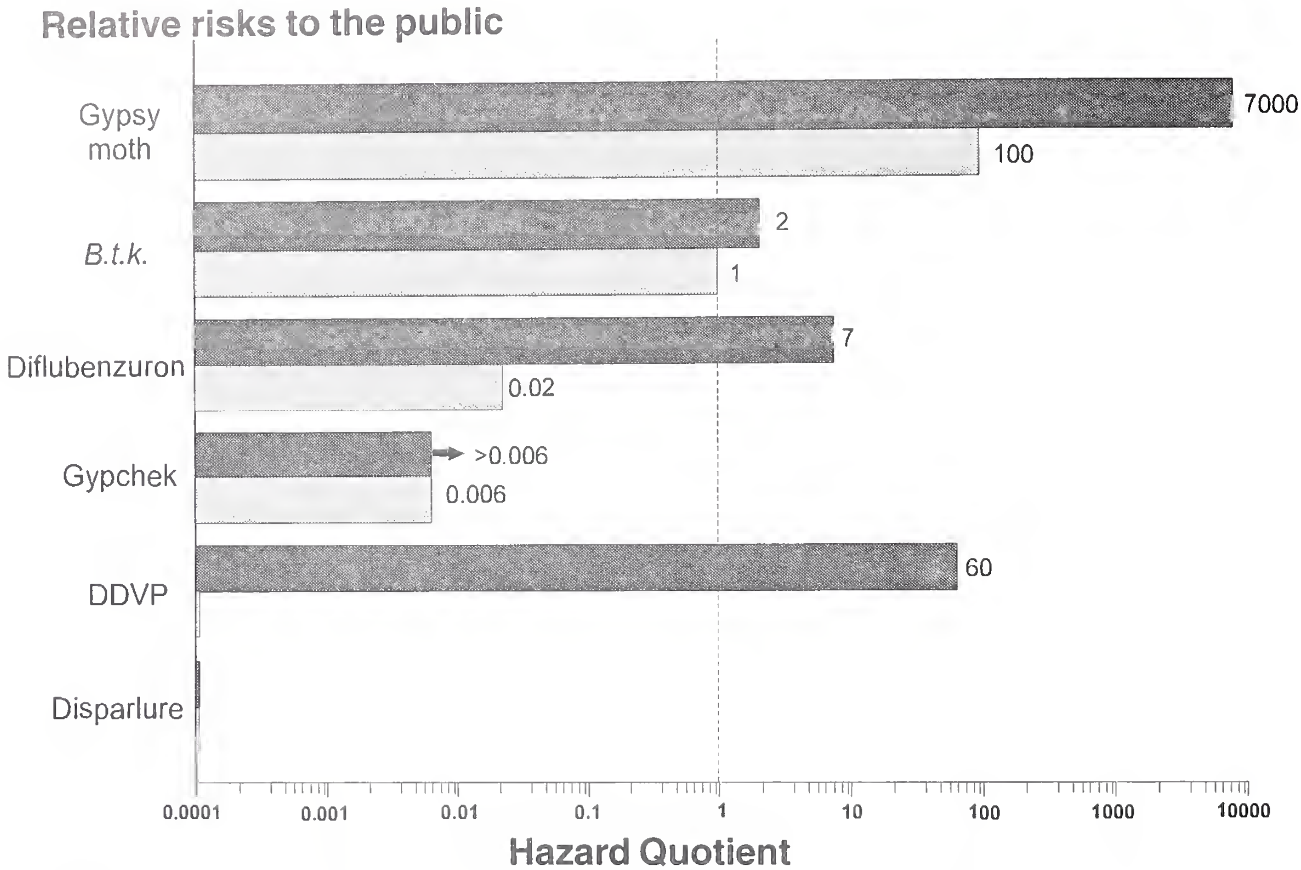


Figure 4-1. A hazard quotient greater than one indicates that the effect may be observed after exposure. Under routine conditions of exposure, the only agent likely to cause a substantial number of adverse health effects is the gypsy moth, although the effects are not severe. Under extreme conditions, *B.t.k.* may be associated with irritant effects in some people. No adverse effects are expected from the use of Gypchek. Diflubenzuron might be associated with a detectable increase in methemoglobin; however, no signs of toxicity would be obvious. If a trap containing DDVP is tampered with, signs of toxicity may develop; they are unlikely to be severe but cannot be ruled out. No health hazard was identified for disparlure. More information on the type and severity of effects is given in the section on Summary of Effects.

addition, because the dose-response assessment is specific to monitoring data from a specific study, the data (in terms of colony forming units) from one study may not be directly analogous to the data from other studies. This imposes substantial limitations on the characterization of risk. These uncertainties notwithstanding, the overall quality of the data on *B.t.k.* can be categorized as being moderate to good (*table 4-1*).

Cumulative Effects

The cumulative effects associated with the application of *B.t.k.* formulations must consider both the residual exposure to *B.t.k.* and formulation products after a single application as well as the effects of multiple applications in a single season and over several years. Monitoring data from the Oregon study (Elliott and others 1986, 1988), demonstrate that levels of *B.t.k.* in air can be detected several days after spraying. Because the dose-response assessment is based on epidemiological studies, it implicitly considers this type of cumulative effect. The effects of multiple exposures over several years, however, cannot be directly assessed. As indicated by a study in British Columbia, effects that may occur are likely to be transient (Cook 1994, Noble and others 1992). In this respect, cumulative effects from spray programs conducted over several years would not be anticipated.

Connected Actions

Workers or members of the general public who are exposed to either aerial or ground sprays of *B.t.k.* will also be exposed to the gypsy moth and may be exposed to other treatment agents. No data were available to suggest that risks posed by these other agents will affect the response, if any, to *B.t.k.* formulations. Similarly, exposure to chemicals in the environment may affect the sensitivity of individuals to *B.t.k.* or other agents. Again, no data were available to permit an assessment of such interactions.

Groups at Special Risk

B.t.k. formulations contain viable microorganisms; therefore, it is reasonable to suggest that immunocompromised individuals may be at special risk. A study in British Columbia, however, did not find immunocompromised individuals to be at special risk due to a gypsy moth spray program (Noble and others 1992). Immunocompromised mice cleared injected *B.t.k.* from their systems without illness, as did immunocompetent mice (Siegel and others 1987).

Little information is available on groups with special sensitivities, such as allergies or chemical sensitivities to *B.t.k.* formulations. In British Columbia only a weakly positive relationship was noted in the incidence of irritant effects between ground workers with and without a history of asthma, seasonal allergies, or eczema (Cook 1994).

Effects Due to Diflubenzuron

Hazard Identification

The oral toxicity of diflubenzuron has been characterized relatively well. Most of the studies were conducted during the 1970's and early 1980's, coinciding with the commercial development and early use of diflubenzuron. The dermal toxicity of diflubenzuron, however, is not well characterized. Standard acute dermal studies indicate that diflubenzuron is poorly absorbed and, therefore, is not likely to cause gross toxic effects. In addition, exposures to substantial levels in air are unlikely. Thus, few studies have been conducted on the inhalation toxicity of diflubenzuron.

The toxicity of diflubenzuron was characterized in several reviews (Booth and others 1987, Maas and others 1980, WHO 1985, Wilcox and Coffey 1978) and in previous environmental impact statements on gypsy moth programs (USDA 1985, USDA Forest Service 1989). The more recent reports about the biological activity of diflubenzuron do not substantially alter the earlier toxicological assessment (Arafah and others 1988, El-Sebae and others 1988, Jenkins and others 1986, Perocco and others 1993). The available data indicate that exposure to diflubenzuron may cause hematological (blood) effects. The potential for carcinogenic or reproductive effects, however, is far less plausible.

Effects on the Blood

Diflubenzuron is known to affect the blood. The most sensitive effect appears to be the induction of methemoglobin and sulfhemoglobin (modified forms of hemoglobin), which are unable to normally transport oxygen in the blood.

Reproductive Effects

Reproductive effects due to diflubenzuron were observed in one report (Smalley 1976), but a review of other available studies on reproductive effects does not support it. In addition, several studies of teratogenicity (birth defects) and reproduction through multiple generations in experimental mammals reported no adverse effects (WHO 1985). Even though diflubenzuron is structurally similar to compounds that have hormonal activity, experimental evidence suggests that diflubenzuron is not estrogenic and is not likely to cause reproductive effects.

Carcinogenicity

Diflubenzuron has been tested for carcinogenicity in rats and mice, and no carcinogenic effects were observed (Keet 1984a,b). In addition, in several tests for genetic changes diflubenzuron caused no mutagenicity or other genetic damage (Arnold 1974, Brusick and Weir 1977a,b,c, Bryant 1976, MacGregor and others 1979, Quarles and others 1980, Seuferer and others 1979, Szabad and

Bennettova 1986). Diflubenzuron may have limited potential, however, to alter genetic material (Kurinnyi and others 1982, Perocco and others 1993).

The weight of evidence on diflubenzuron clearly does not suggest a high potential for causing cancer. These data, however, have not been formally evaluated by the International Agency for Research on Cancer (1982) or the U.S. EPA (1987b, p. 1-12). Using the U.S. EPA classification scheme, diflubenzuron could be classified in Group E—Evidence of Non-Carcinogenicity, defined as giving ". . . no evidence for carcinogenicity in at least two adequate animal tests in different species . . .".

A mammalian metabolite of diflubenzuron, 4-chloroaniline, has been shown to have mutagenic potential (Prasad 1970) and cancer-causing activity in rats and mice (NCI 1979, 1989). Because studies showed cancer-causing activity in more than one species, the U.S. EPA has classified 4-chloroaniline in Group B2—Probable Human Carcinogen.

Physiological Processes

Because diflubenzuron interferes with chitin synthesis in insects, potential effects on analogous processes in vertebrates (for example, synthesis of connective tissue) were considered. Studies have found no evidence of these effects (Maas and others 1980).

Inert Ingredients and Impurities

A commercial formulation of diflubenzuron, Dimilin 4L, contains inert ingredients, including relatively small quantities of an antifreeze and a paraffin-based carrier. In addition, Dimilin contains small amounts of other benzoylphenylurea insecticides. The exact chemical composition of these other compounds has not been identified (Dynamac Corporation 1984). All of the toxicity studies reviewed for the risk assessment used diflubenzuron that included these impurities. Therefore, the risk assessment incorporated any effects that may have been attributable to these other compounds.

Exposure Assessment

Workers

Two general scenarios were evaluated for worker exposure to diflubenzuron: job-specific and incident-specific (accidental). The job-specific assessments estimated absorption associated with relatively complex job activities, such as mixing, loading, or applying diflubenzuron, in which multiple routes of exposure were likely. Doses were calculated based on scenarios that would encompass routine and extreme exposures. Incident-specific assessments were simpler. They estimated absorption either from spilling diflubenzuron onto the skin or wearing clothing saturated with diflubenzuron. Absorption rates were estimated on the basis of a relationship of absorption rate to molecular weight (Durkin and others 1995, Rubin and others 1994). Although these scenarios represented accidental occurrences, both routine and extreme exposures were analyzed.

No studies were available regarding occupational exposure to diflubenzuron. Consequently, estimation methods were based on worker exposure to other pesticides.

Workers have a greater chance of exposure to insecticides than do members of the public.

Doses to aerial spray workers were calculated for pilots, flagmen in the treatment area, and for mixers and loaders. Calculated doses to pilots were intermediate to doses to flagmen (lowest) and mixers and loaders (highest), under routine and extreme exposure conditions. Doses were calculated for ground spray workers under routine and extreme exposure conditions.

Doses to workers from possible accidents were calculated for (1) complete immersion of both hands in diflubenzuron for 1 minute (routine exposure); and (2) for a spill in which diflubenzuron covered the lower legs, and the individual could not wash for 24 hours (extreme exposure).

Public

The exposure scenarios for the general public incorporated conservative assumptions, assuming maximum application rates and no interception of spray by trees. Many of the scenarios involved a child.

The lowest calculated dose from dermal exposure was from exposure of an unclothed child to a direct spray of diflubenzuron, assuming the child was washed completely 1 hour after being sprayed. The highest calculated dose was from an extreme exposure in which an unclothed child was saturated with diflubenzuron following the emergency ejection of a full tank of insecticide from a plane. In this case also, the child was assumed to be washed after 1 hour. Intermediate doses were calculated from scenarios in which a child touched contaminated surfaces, such as grass or other vegetation.

Scenarios used to analyze oral exposures resulted in the lowest doses from consuming cow's milk under routine exposure, in which a child drinks 1 liter (1.1 qt) of milk per day from a cow that ate vegetation with an annual average level of diflubenzuron. The highest dose was from consuming cow's milk under extreme exposure, in which a child drinks 1 liter of milk from a cow that ate vegetation that had just been sprayed. Drinking from a water source that had been directly sprayed or eating game animals that had been contaminated by eating sprayed vegetation resulted in doses that were intermediate between the two cow's milk scenarios.

Some of the same scenarios were used to calculate doses of 4-chloroaniline that would result from exposures to diflubenzuron. A low dose was determined for a person consuming 0.14 kg (4.9 oz) of fish per day from a water source that had been sprayed with diflubenzuron 1 month earlier. On the high end was a dose for a child drinking 0.5 liter of water from a water source directly sprayed with diflubenzuron.

Dose-Response Assessment

Based on the hazard identification, dose-response relationships were derived for blood effects and cancer. For both effects, the dose-response relationships for diflubenzuron and 4-chloroaniline were assessed separately.

Effects on the Blood

The verified reference dose for diflubenzuron is 0.02 mg/kg/day (U.S. EPA 1994b) based on a 1-year dog feeding study in which the no-observed-effect level (NOEL) was 2 mg/kg/day, and the lowest-observed-adverse-effect level (LOAEL) was 10 mg/kg/day (Duphar B.V. 1985). The critical effect for this reference dose was the formation of methemoglobin and sulfhemoglobin. To derive the reference dose, the NOEL was divided by an uncertainty factor of 100, intended to account for intraspecies and interspecies differences. Confidence in the principal study, the database for toxic effects, and the reference dose itself is high (U.S. EPA 1994b). The reference dose was reviewed in September 1990, and no subsequent data were located in the literature to alter this assessment. In this case, the reference dose was accepted as the RRV for the general public as well as workers, and was used without modification.

An important issue with regard to evaluating risks when the exposure exceeds the RRV is the relationship of the formation of methemoglobin and sulfhemoglobin to clinically significant adverse effects. Normal levels of methemoglobin in humans and the clinical consequences of increased levels of methemoglobin are reasonably well characterized. The clinical significance of varying levels of sulfhemoglobin is less well characterized.

In normal human populations, levels of methemoglobin range from about 0.6 percent to less than 4 percent. Some but not all studies indicate that levels tend to be higher in smokers than in nonsmokers. At methemoglobin levels of approximately 10 percent, blood is dark brown, indicating an impaired ability to transport oxygen; however, obvious signs of toxicity at this level have not been reported (Jaffe 1981). At methemoglobin levels between 20 percent and 45 percent, signs of toxicity, such as cyanosis, are apparent and require medical intervention. Levels as low as 50 percent have been characterized as life threatening (Daly and others 1983). Levels greater than 70 percent clearly are life threatening (Jaffe 1981).

Carcinogenicity

The U.S. EPA-derived reference dose for 4-chloroaniline is 0.004 mg/kg/day (U.S. EPA 1994b). The critical effect for this reference dose is the formation of nonneoplastic (non-tumor-forming) lesions of the spleen in rats. This reference dose is based on a 2-year feeding study in rats in which the critical effect was observed at the lowest dose tested, 250 parts per million (ppm) in the diet (12.5 mg/kg/day) which is considered a LOAEL (NCI 1979). To derive the reference dose, the LOAEL was divided by an uncertainty factor of 3,000 intended to account for intraspecies and interspecies differences and the extrapolation from a LOAEL to a NOAEL. An additional factor of 3 was incorporated into the uncertainty factor because supporting reproductive and other toxicity data were lacking. Confidence in the principal study, the data base for toxic effects, and the reference dose itself is low (U.S. EPA 1994b). The reference dose was accepted as the RRV for the general public and used without modification.

The cancer potency for 4-chloroaniline was based on a National Cancer Institute bioassay on rats and mice (NCI 1989). Using the general procedures outlined by the U.S. EPA (1986), the cancer potency for humans was determined to be 0.0638 per mg/kg/day.

Quantifying the potential cancer-causing effects from direct exposure to diflubenzuron is more difficult than to do the same for 4-chloroaniline. Methods for estimating carcinogenic risk for a compound that is negative in cancer bioassays but is metabolized to a carcinogen have not been proposed. Therefore, a consideration of the potential carcinogenic activity of diflubenzuron is made under the assumption that—in the body—diflubenzuron may be converted to 4-chloroaniline, which could pose a potential cancer risk. Based on these extremely conservative assumptions, the human cancer potency for diflubenzuron was determined to be 0.0001 per mg/kg/day. On the basis of this estimate, the relative potency of diflubenzuron with respect to 4-chloroaniline was 0.002. Therefore, the risk associated with a dose of 10,000 ppm diflubenzuron would be equivalent to the risk of a dose of 20 ppm 4-chloroaniline.

Risk Characterization

The most sensitive effect from exposure to diflubenzuron is the occurrence of methemoglobinemia, a condition that impairs the ability of the blood to carry oxygen. Clinical signs of toxicity do not normally begin to occur until the level of methemoglobin exceeds 10 percent in the blood. Levels above 50 percent can be fatal. Values for the highest dose levels that will not induce methemoglobinemia have been derived for both workers and the general public. These values have been compared with estimates of dose derived from the exposure assessment to calculate a hazard quotient.

Hazard quotients determined for aerial spray workers, for both routine and extreme exposures, were all less than 1, indicating that these workers are not at risk of adverse effects from gypsy moth project operations that use diflubenzuron (*fig. 4-1*). The routine scenario for ground application workers also resulted in a low hazard quotient. Based on extreme exposure, however, a ground worker treating 15 acres per day (the upper limit of number of acres one person would treat in a day) may experience detectable, but transient, changes in the blood. No overt signs of toxicity or residual damage would be expected.

Scenarios representing workers involved in accidental exposures also resulted in hazard quotients less than 1 if they washed within an hour. Therefore, accidents would not cause concern about the health

effects on these workers. Circumstances that prevent a worker from washing until 24 hours after spilling diflubenzuron on the lower legs would be cause for concern. In this case the hazard quotient could be as high as 40.

A number of scenarios were analyzed to help characterize risk to the general public. The calculated hazard quotients were less than 1 for most of these public exposures, therefore, adverse health effects clearly are not anticipated. The hazard quotients for a few of the extreme scenarios ranged from 2 to 7. Even in these cases, no clinically significant effects are likely. At the highest exposure, increases in certain blood pigments may be detected, but they will not be long lasting.

Under all circumstances in all scenarios where the potential for cancer was considered, the upper limit of cancer risk was less than one in 1 million. Therefore, the risk of workers or the general public developing cancer from exposure to either diflubenzuron or the metabolite 4-chloroaniline was less than one in 1 million. The scenario that represented the greatest risk was the one that incorporated chronic exposure through consumption of contaminated water, milk, fish, and vegetables. Under the conservative assumption that someone could be exposed to all of these contaminated food sources, the cancer risk was determined to be two in 10 million, that is, it should elicit no concern about developing cancer.

Uncertainties

The main sources of uncertainty regarding diflubenzuron are estimates of dermal absorption, dose-severity relationships for effects on the blood, and the potential cancer risk. These uncertainties have been addressed by using conservative estimates that are over-protective of people. The overall quality of the data on diflubenzuron can be categorized as being moderate to good (*table 4-1*).

Cumulative Effects

Any cumulative effects from the use of diflubenzuron are likely to be additive if the exposures are in the same treatment season, that is, diflubenzuron is applied twice in one season. No cumulative effects are expected from one year to the next, with the exception that carcinogenic risks have been calculated based upon a cumulative lifetime average dose. Therefore, the risks of a single exposure at 1.0 ounce a.i./acre (69 g/ha) is identical to two applications at 0.5 ounce a.i./acre (34.6 g/ha). Since the risk assessment used maximum application rates in determining risk and any effects are likely to be additive rather than synergistic, cumulative effects due to diflubenzuron essentially have been addressed.

Connected Actions

No data were found to indicate that exposure to diflubenzuron will affect the way people respond to other agents used in gypsy moth treatment projects. Also, the most sensitive effect of diflubenzuron, methemoglobinemia, is not associated with the use of any of the other agents. Therefore, the other agents are not expected to interact with diflubenzuron or result in an additive response. If other compounds in the environment induce methemoglobinemia, then an additive effect may be noticed. Individuals exposed to combustion smoke or carbon monoxide may be at increased risk of developing methemoglobinemia (Hoffman and Sauter 1989, Laney and Hoffman 1992). Also, individuals exposed to high levels of nitrates, in either air or water, will have increased levels of methemoglobinemia (Woebkenberg and others 1981) and may be at increased risk from exposure to compounds such as diflubenzuron.

Groups at Special Risk

Some individuals are born with a form of congenital methemoglobinemia and may be at increased risk of adverse effects from compounds that induce methemoglobinemia (Barretto and others 1984). Infants less than 3 months old have higher levels of methemoglobin than do older children and adults and may be at increased risk if exposed to diflubenzuron contamination (Centa and others 1985, Khakoo and others 1993, Nilsson and others 1990). Individuals with diseased or damaged skin may absorb chemicals such as diflubenzuron at a substantially greater rate than do normal individuals.

Effects Due to Gypchek

Gypsy moth nucleopolyhedrosis virus is a naturally occurring virus that may be partially responsible for the collapse of outbreak gypsy moth populations (Podgwaite 1979). Gypchek, a powdered formulation of the virus, was developed and registered by the U.S. Department of Agriculture (USDA) for control of the gypsy moth. A similar product, Disparvirus, was developed in Canada (Nealis and Erb 1993). Because the powdered formulation is produced by culturing and processing gypsy moth caterpillars infected with the virus, the major portion (80 percent) of the formulation consists of gypsy moth parts.

Hazard Identification

Specific information on the human health effects of the nucleopolyhedrosis virus were not found in the available literature. Data that are available and the unpublished toxicity data on mammals submitted to the U.S. EPA as part of the virus registration package indicate that it may be an eye irritant and, possibly, a skin irritant.

Studies in immunosuppressed mice and guinea pigs exposed to Gypchek indicate that it does not cause infection, nor is it likely to cause effects in people with compromised immune systems. Individuals with preexisting allergies, however, may be at greater risk because of possible sensitivity to the gypsy moth parts in the formulation.

Short- and long-term toxicity tests in experimental mammals have not demonstrated toxicity to the virus at doses up to 3,750 mg/kg. A no-observed-effect level of 45 mg/kg was determined in a 2-year feeding study with rats. The lack of oral toxicity in experimental mammals is supported by feeding and field studies in wildlife.

Given that Gypchek contains 80 percent gypsy moth parts and that exposure to the gypsy moth has been associated with respiratory effects in humans (see the section on Effects Due to the Gypsy Moth), respiratory irritation at some level of exposure seems plausible and is supported by animal data. Animals exposed to 6.12 mg/L (6,120 mg/m^3) were inactive and had labored respiration. In addition, eye irritation might be inferred because the animals kept their eyes shut. There was no indication, however, of any systemic or respiratory pathology. No adverse effects have been observed in animals exposed to Gypchek doses ranging from 0.028 to 0.81 mg/L.

Dermal exposure to the gypsy moth has been associated with skin irritation in humans; however, this effect was not observed in rabbits in two skin irritation studies using Gypchek. Because skin irritation in humans may be an allergic reaction, the relevance of the negative findings in experimental mammals may be limited.

Gypchek has been shown to cause eye irritation in experimental mammals. This is consistent with the human health effects of exposure to gypsy moth parts. Gypchek powder applied to one eye of rabbits caused mild conjunctival irritation, preventable by washing (Cannon Laboratories 1976b). Exposure concentrations of 50 mg caused effects on the cornea and iris, which were not eliminated by washing the eye shortly after exposure, under the conditions of the experiment (Litton Bionetics 1977).

In response to concerns that Gypchek might become contaminated, the USDA Forest Service has developed a quality control program to ensure that batch preparations do not contain harmful bacteria (Podgwaite and Bruen 1978). Tests for a number of bacteria and an *in vivo* pathogenicity test in mice are performed on each batch of Gypchek.

A USDA-funded study suggested that the virus may cause permanent changes, which have not been characterized, in vertebrate cells (Padhi 1977). Other studies of this nature were not found in the available literature. Antibodies to the virus were not observed in the bloodstream of laboratory workers exposed to the gypsy moth virus (Mazzone and others 1976, Tignor and others 1976).

Exposure Assessment

As indicated by the hazard identification, dermal and inhalation exposures to Gypchek are potential concerns to workers and the general public. During aerial and ground applications both workers and the general public may be exposed to the nucleopolyhedrosis virus by the skin and respiratory tract. Oral exposure is likely to be incidental to

dermal and inhalation exposure. Therefore, a separate oral exposure assessment does not seem warranted.

Neither personal nor general air monitoring data for workers or the general public are available. There are methods for estimating worker exposure to chemicals based on the amount of material handled and job category; however, these methods are not applicable to biological agents.

Caterpillars killed by the nucleopolyhedrosis virus appear wilted and shiny, and often hang limply in an inverted "v" position.

Dose-Response Assessment

Lethargy, respiratory depression, and eye irritation from Gypchek have been observed in experimental mammals after 1 hour of inhalation exposure to 6,120 mg/m^3. This concentration may be regarded as an adverse-effect level (AEL). No-observed-effect levels (NOELs) range from 0.028 mg/L to 0.81 mg/L. The geometric mean of these values, which can be used as a measure of central tendency, is 0.15 mg/L or 150 mg/m^3. This NOEL may be divided by 100 (10 for species extrapolation and 10 for sensitive individuals) to yield a short-term respiratory risk reference value of 1.5 mg/m^3.

The available data on dermal irritation from Gypchek are not adequate for a dose-response assessment. Eye irritation has been observed after direct application of Gypchek concentrations as low as 3 mg/eye. Although the severity of eye irritation has been shown to increase with dose, a NOEL has not been demonstrated.

Oral toxicity, which is not a primary concern with Gypchek, has been well characterized in experimental mammals. NOELs for short-term exposure to as much as 3,200 mg/kg have been reported, and the highest NOEL for chronic oral exposure is 45 mg/kg from a rat feeding study. Using standard methods, a chronic oral RRV for humans can be derived by dividing the chronic NOEL of 45 mg/kg/day by 100 (10 for species extrapolation and 10 for sensitive subgroups). Thus, the oral risk reference value is 0.45 mg/kg/day. The use of this RRV for applications of Gypchek would be highly conservative because it represents a daily dose that is not expected to cause adverse effects over a lifetime exposure. An acute RRV of 32 mg/kg/day was derived based on the acute NOEL of 3,200 mg/kg, using an uncertainty factor of 100.

Risk Characterization

Gypchek, like commercial formulations of *B.t.k.*, may be applied over relatively large areas; therefore, exposure may affect both workers and the general public. As with commercial formulations of *B.t.k.*, the active ingredient in Gypchek is a biological agent. Unlike commercial formulations of *B.t.k.*, Gypchek has not been used extensively, so human experience with this agent is limited. There are no epidemiological, clinical, or anecdotal data regarding the human health effects of exposure to Gypchek. Furthermore, monitoring studies have not been conducted on levels of Gypchek in air after aerial application, and there are no data regarding worker exposure to the agent.

Based on recommended application rates, conservative exposure assumptions, and available animal toxicity data, risks to both workers and the general public seem to be minimal. Eye irritation may be an effect of concern for workers if the material is splashed directly into the eyes. The general public is far less likely to be exposed in this manner.

Human Health Effects

For the general public, low risks are associated with inhalation, dermal, or oral exposure to Gypchek at application rates as high as the maximum proposed rate of 1×10^{12} OB/acre. Air concentrations as high as 0.3 mg/m^3 are plausible at this application rate. The acute inhalation risk reference value for Gypchek, based on a 1-hour exposure period, is 1.5 mg/m^3. This RRV covers responses such as respiratory irritation, eye irritation, and general toxic effects. Using a 2-minute duration of exposure, the hazard quotient is 0.006.

The potential for dermal effects is problematic. Because Gypchek contains a substantial amount of gypsy moth parts, dermal effects might be anticipated; however, skin irritation from exposure to Gypchek has not been observed in test animals. The lack of dermal effects in laboratory animals may indicate that the species tested are insensitive. This uncertainty in the risk assessment cannot be quantified without additional experimental data. Therefore, data were inadequate for a quantitative characterization of risk (*table 4-1*).

Oral exposure is not a primary concern with Gypchek, so that a quantitative exposure assessment was not performed. The maximum application rate of 1×10^{12} OB/acre corresponds to approximately 18,300 mg/acre. Using the acute oral RRV of 32 mg/kg and assuming an adult male body weight of 70 kg, a risk reference value equivalent is applied to each 0.122 acres (500 m^2). Thus, at this RRV, an adult would have to consume all of the Gypchek applied to 500 m^2 to reach the acute RRV. For a 10 kg child, a RRV equivalent is applied to each 73 m^2. Even if these levels were consumed, which seems highly unlikely, there is no evidence that exposure would approach a toxic threshold.

No data were available from which to assess exposure or potential risks to workers. By analogy to commercial formulations of *B.t.k.* and other insecticides, workers, especially those involved in ground applications, are more likely than the general public to be exposed to high levels of Gypchek. The effects of concern would be similar to those for commercial formulations of *B.t.k.*, including eye, skin, and respiratory tract irritation. No assessment, however, can be made regarding the likelihood of any of these effects being observed.

Uncertainties

Data on human toxicity and exposure to Gypchek are lacking. Since Gypchek is about 80 percent gypsy moth parts, the known effects of human exposure to gypsy moth caterpillars might also be observed after exposure to Gypchek. The available data indicate that adverse human health effects due to the gypsy moth are most often associated with exposure to early instars; however, Gypchek is produced from later and much larger instars. It is not clear whether the toxic or allergenic agents from caterpillars persist in Gypchek and, if they do, at what levels they are present. Additionally, when Gypchek is applied at the maximum allowed application rate, the amount of gypsy moth parts per acre would be equivalent to approximately 667 caterpillars. This is a modest number when compared with the 10,000-100,000 caterpillars per acre that survive to later instars during gypsy moth outbreaks.

Cumulative Effects

Given the low apparent risk associated with one application of Gypchek at the maximum application rate, repeated exposure over one or more spray seasons is not expected to result in any appreciable increase in risk. This assessment must be tempered, however, by the uncertainties associated with a lack of any toxicological data on humans. Because Gypchek contains gypsy moth parts and some individuals may have allergic reactions to the gypsy moth, allergic reactions to Gypchek are plausible but speculative.

Connected Actions

No data exist that would permit assessment of the consequences of connected actions involving gypsy moth program activities or other common activities. Again, because Gypchek may cause irritant effects similar to those caused by the gypsy moth, exposure to both caterpillars and Gypchek could be additive. Again, this assessment is speculative.

Groups at Special Risk

The available data suggest that immunocompromised animals are not at increased risk from exposure to Gypchek. By analogy to the

human health effects from exposure to gypsy moth caterpillars, individuals with preexisting allergies may be at greater risk of effects from Gypchek.

Effects Due to DDVP in Mass Trapping

The milk carton trap used in areas where the number of male moths (more than 15) is likely to overwhelm the sticky interior of the delta trap, also contains the organophosphate insecticide DDVP (dichlorvos). DDVP may pose a health risk to workers who assemble and deploy the traps, and to individuals who might tamper with a trap and come into contact with the DDVP.

Human health risks from exposure to the pheromone disparlure, which is used to attract male moths to both delta and milk carton traps, is addressed in the next section on Effects Due to Disparlure in Mating Disruption.

Hazard Identification

The DDVP is formulated as Vaportape II, a strip consisting of a 1- by 4-inch red, multilayered polyvinyl chloride (PVC) tape containing 590 mg of DDVP. The average thickness of the strip is 67.5 mil (equal to 0.0675 inch) (Hercon 1994).

In addition to DDVP, each strip contains compounds (0.75 percent) that are related to DDVP. Commercial grade DDVP contains impurities that are known to be or are likely to be toxic (Gillett and others 1972a, IARC 1991, WHO 1989). These impurities are encompassed in the risk assessment of DDVP because the dose-response assessment is based on studies that used commercial grade DDVP. Therefore, the results of those studies are directly applicable to the risk assessment.

Cholinergic Effects

Like all organophosphate insecticides, DDVP combines with and inhibits acetylcholinesterase. Depending on the dose and duration of exposure, and the resulting degree of acetylcholinesterase inhibition, organophosphate insecticides may induce a broad spectrum of effects on the nervous system. The effects of DDVP on acetylcholinesterase inhibition are well documented in studies involving humans, wildlife, and experimental mammals (Gillett and others 1972a,b; IARC 1979, 1991; WHO 1989).

DDVP also inhibits other cholinesterases outside the nervous system and induces clinical signs of intoxication consistent with those of acetylcholinesterase inhibition. Substantial inhibition of cholinesterases in plasma and blood is not associated, necessarily, with clinically significant adverse effects (Gage 1967, Wills 1972). Generally, 50 percent inhibition of normal cholinesterase levels after exposure is regarded as clinically significant (ATSDR 1993).

Oral LD_{50} values for experimental mammals ranged from 25 to 300 mg/kg (Gaines 1969, Jones and others 1968, Muller 1970, Wagner and Johnson 1970). All of these studies were based on the administration of DDVP in vehicles that do not inhibit absorption. The containment of DDVP in a slow-release vehicle, such as PVC, inhibits acute toxic effects.

Several studies demonstrated that DDVP does not induce delayed damage to the peripheral nervous system (WHO 1989). Nonetheless, administration of high doses of DDVP to hens has resulted in clinical neuropathy (Johnson 1978, 1981).

Carcinogenicity and Mutagenicity

DDVP produced positive results in mammalian bioassays for carcinogenicity. In a mouse cancer bioassay, a significant dose-related increase in cancers of the forestomach were found in both sexes, a significant dose-related increase in the incidence of cancers of the pancreas was observed in the males, and a significant increase in the incidence of cancers of the mammary gland was found in females (NCI 1977). Neither of two other bioassays conducted on the carcinogenicity of DDVP after oral exposure indicated significant evidence of carcinogenicity (IARC 1991).

No significant increase of tumor incidence was observed in a study to determine carcinogenicity of DDVP from inhalation exposure (Blair and others 1976); however, not all the rats were necropsied.

Therefore, the usefulness of this study is limited for assessing the potential carcinogenicity of DDVP with respect to inhalation exposure (IARC 1991).

Case studies of four children with aplastic anemia and one child with acute lymphoblastic leukemia who were exposed to DDVP in the course of normal household use (Reeves and others 1981) were inadequate for determining the potential human carcinogenicity of DDVP (IARC 1991). More recent studies have found positive associations between childhood brain cancer and exposures to DDVP during childhood or during pregnancy (Davis and others 1992, 1993).

Based on the available data, DDVP is classified as a Group C—Possible Human Carcinogen by the U.S. EPA (Irene 1995). This classification is given because data are inadequate to assess the potential carcinogenicity of DDVP in humans, and only limited data indicate that DDVP is carcinogenic to experimental animals by oral exposure. The U.S. EPA has further concluded that it is inappropriate to quantitate human cancer risks from dermal and inhalation exposures to DDVP (Irene 1995).

DDVP has been tested extensively for mutagenicity, and data reviews are available (IARC 1979, 1991; Ramel and others 1980). Mutagenic effects as well as covalent binding to RNA and DNA have been demonstrated in bacterial systems.

Reproductive and Teratogenic Effects

According to some studies, exposure to DDVP caused birth defects (teratogenic effects) and reproductive effects in laboratory animals (Dambska and others 1979, Kimbrough and Gaines 1968), and adverse testicular effects in treated male mice (AMVAC Chemical Corporation 1989). On the other hand, in several breeding studies no adverse reproductive effects or birth defects were observed in rabbits, swine, or experimental mammals after exposure to DDVP (Stanton and others 1979, Vogin and others 1971).

Skin Irritation

Studies on experimental animals suggest that DDVP may cause skin irritation, allergic reactions, or both (Arimatsu and others 1977, Fujita 1985). Human data regarding the dermal effects of DDVP are relatively sparse but generally support the animal studies (Bisby and Simpson 1975). A report summarizing exposure of the general public to DDVP pest strips, which involved predominantly dermal contact with the insecticide, suggested that irritant or allergic responses are possible (U.S. EPA 1981). On the other hand, no dermal effects were noted in 21 individuals in which skin contact with the strip was maintained for 30 minutes (Zavon and Kindel 1966).

Other Effects

Animal studies suggest that exposure to DDVP may be associated with immunosuppression and effects on diurnal rhythm (normal daily cycles) (Casale and others 1983; Desi and others 1978, 1980). One study found alteration in the diurnal rhythm of the pituitary-adrenal axis in rats exposed to DDVP, and changes in hormone levels (Civen and others 1980). No effects on antibody production, however, were noted in *in vivo* studies (Dunier and others 1991). DDVP was reported to interfere with the normal circadian rhythm (variation in metabolic rate) of red blood cell acetylcholinesterase in mice and humans (Jian and Zhiying 1990).

Exposure Assessment

Two exposure scenarios were considered for DDVP: a child exposed to a strip after tampering with a trap, and workers assembling traps indoors. These are the most likely circumstances of potential exposure because of the use of DDVP in traps for the gypsy moth program.

Children

A child tampering with a trap may be exposed to DDVP through two significant routes: skin contact and ingestion. For skin contact, it was assumed that the child removes and handles a DDVP strip. Children as young as 2 years old have been exposed to DDVP through handling No-Pest Strips or flea collars (U.S. EPA 1981). This exposure scenario is based on the assumptions that the child's age is between 2 and 3 years, that the child weighs 11 kg, and has a total body surface area of 0.6 m^2 (U.S. EPA 1992a), and that contact occurs for 1 hour for the routine scenario and 4 hours for the extreme scenario.

Based on the above assumptions, the routine scenario for dermal contact would result in an absorbed dose of 2.2 x 10^{-2} mg/kg. For the extreme scenario, the absorbed dose would be higher by a factor of 4 (8.8 x 10^{-2} mg/kg). A 1-minute exposure, which may be the most likely situation, would result in an absorbed dose of 4 x 10^{-4} mg/kg.

For oral exposure, it was assumed that a child weighing between 10 and 30 kg, which corresponds to an age range of 1-10 years (U.S. EPA 1987a), removes a strip and chews on it. Anecdotal reports seem to support the position that prolonged exposure to the strips is unlikely (U.S. EPA 1981). Since absorption is dependent on the duration of exposure and the nature of contact (such as licking, or chewing and swallowing), it was assumed for the routine scenario that 5 percent and for the extreme scenario that 100 percent of the available DDVP was absorbed from the strip. Based on these assumptions, the routine scenario for oral exposure would result in an absorbed dose of 1-3 mg/kg. The extreme scenario would result in an absorbed dose of 20-60 mg/kg.

Workers

For workers, exposures that could occur during assembly, transport, and installation of the traps containing the DDVP strips would predominantly be through the respiratory tract and skin. Exposure through either route is negligible if proper handling procedures are followed (that is, if the traps are assembled outdoors or in a well-ventilated area and skin contact with the strip is avoided). Therefore, for the routine scenario, both exposures are considered to be negligible. For the extreme scenario, however, it was assumed that the worker does not follow proper handling procedures (that is, the traps are assembled and transported in an enclosed environment and no gloves are worn, or no care is taken to avoid contact with the strips).

For the extreme scenario, it was assumed that an individual worker assembled 75 traps per day, that the traps were placed in a garage for 8 hours overnight, and then transported for 4 hours in a vehicle driven by the worker. The worker would be exposed via inhalation to a level of DDVP ranging from 0.1-0.2 mg/m^3 while assembling the traps and 0.5-1 mg/m^3 while driving. Skin contact with the strips during assembly of the traps would result in a dose of 0.004 mg/kg for the extreme scenario, considering improper handling of the strips.

Dose-Response Assessment

Cholinergic toxicity is the effect of primary concern. DDVP causes this effect in humans under exposure conditions similar to those described in the exposure scenarios evaluated. In addition, the significance of this effect is unequivocal. Cancer is also a concern because DDVP has been classified as a potential or probable human carcinogen. All of the studies supporting the carcinogenic activity of DDVP, however, involve relatively prolonged periods of exposure. Using these studies to estimate the risks associated with short-term exposure is highly uncertain. Testicular atrophy was observed in mice after chronic exposure to 94.8 mg/kg/day (AMVAC Chemical Corporation 1989). Since this effect was observed at dose levels higher than those associated with neurological effects, it was not assessed separately.

Immunosuppression and the disruption of circadian rhythm are also associated with DDVP exposure. Effects associated with immunosuppression have been observed at exposure levels that are lower than those associated with marked acetylcholinesterase depression. Effects on immune function and circadian rhythm are not considered, however, in the data on which the reference dose is based (U.S. EPA 1994b).

Several studies have shown that DDVP exposure affects immune function in mammals and fish; however, the toxicological significance of these studies is not clear. Chronic studies on the oral toxicity of DDVP showed no adverse effects in several animal species. Nevertheless, DDVP is carcinogenic to mammals and has been associated with cancer in humans, so immune suppression cannot be ignored as a contributing factor. In this respect, the cancer analysis may partially encompass concern for the effects of DDVP on immune function.

The reference dose for DDVP is 0.0005 mg/kg/day (U.S. EPA 1994b) and is based on a 1-year dog feeding study in which plasma and red blood cell cholinesterase inhibition was observed in males and females, and brain cholinesterase inhibition was observed in males (AMVAC Chemical Corporation

1990). The NOAEL for this effect was 0.05 mg/kg/day and the LOAEL was 0.1 mg/kg/day. An uncertainty factor of 100 was used to derive the reference dose to reflect the uncertainties associated with interspecies extrapolation and intraspecies variability. Confidence in this reference dose is ranked as medium (U.S. EPA 1994b). A confidence rating of high was not given because of dosing changes in the AMVAC (1990) study and because a rabbit developmental toxicity study and studies that fully address chronic and reproductive toxicity in rats are not available.

The acute oral risk reference value was set at 1 mg/kg, a factor of about 10 below the dose associated with marked acetylcholinesterase inhibition. This dose should not be associated with any observable effects. Exposures of approximately 10 mg/kg/day are of concern because of acetylcholinesterase inhibition, but obvious effects are not expected to occur until exposures reach 100 mg/kg/day. This RRV can be applied to both young children and adults. Young children (older than 1 year) do not appear to be more sensitive to DDVP than adults. This RRV was not applied to infants, which may be a sensitive subgroup.

The threshold limit value for DDVP is 0.9 mg/m^3 (ACGIH 1991). Based on an assessment of inhalation studies in humans, this may be associated with a 20 percent reduction in plasma cholinesterase activity. Because of the carcinogenicity of DDVP, this threshold limit value is under review. Inhalation exposures to DDVP at concentrations greater than 1 mg/m^3 require the use of a supplied-air respirator or self-contained breathing apparatus (NIOSH 1981). The threshold limit value of 0.9 mg/m^3 was adopted as the inhalation RRV for workers, to protect against cholinergic effects.

For dermal exposures, a short-term RRV was calculated based on a human study in which 80.6 cm^2 (12.5 in^2) sections of a DDVP strip were affixed to the skin of volunteers for half an hour on 5 successive days (Zavon and Kindel 1966). No significant decrease in acetylcholinesterase activity was observed. These exposures correspond to an absorbed dose of 0.005 mg/kg, which was taken as the NOEL. This value was divided by a factor of 10 for sensitive individuals. The resulting dermal RRV of 0.0005 mg/kg is identical to the oral reference dose derived by the U.S. EPA.

Assessing the consequences of exceeding the RRV for dermal exposure is difficult. As noted above, the dermal RRV should not be associated with any decrease in acetylcholinesterase activity; nonetheless, the RRV for inhalation exposure, 0.9 mg/m^3, may be associated with a 20 percent reduction in acetylcholinesterase activity. Assuming that all of the DDVP in inhaled air is absorbed and that an average man inhales 10 m^3 during a work day, the absorbed dose associated with the inhalation RRV is 0.13 mg/kg, or about a factor of 25 above the worker RRV for dermal exposure.

More severe effects, including death, must be estimated from the available animal data. The lowest dose lethal to female rats was 38 mg/kg for both oral and dermal exposures (Gaines 1969). The estimate of the LD_1 for female rats was 26 mg/kg for oral exposure and 24 mg/kg for dermal exposure. Using these data and assuming that humans are 10 times more sensitive than rats, the approximate lethal dose for humans, assuming complete absorption, is estimated to be 2 mg/kg, or a factor of about 4000 above the oral or dermal RRV.

Risk Characterization

Exposure to DDVP is associated with adverse health effects in humans and laboratory animals. The compound is known to inhibit acetylcholinesterase, an enzyme involved in the regulation of the nervous system. Sufficiently high acetylcholinesterase inhibition causes serious toxic effects including death. Acetylcholinesterase inhibition is the most sensitive effect of clear clinical significance. Other effects, such as those on reproductive function, occur only at much higher doses and over longer periods of exposure than those anticipated in gypsy moth projects. DDVP has been shown to cause cancer in laboratory animals, and some studies suggest that DDVP causes various forms of cancer in humans.

Under conditions of normal handling and use, DDVP strips are unlikely to present any significant risk to workers or the general public. If the strips are not handled properly during trap assembly and transport, however, exposure will approach or exceed acceptable levels. Left undisturbed, the traps pose no significant risk to members of the

general public. Nonetheless, the traps may be accessible, and individuals may remove and touch the DDVP strip. Under these circumstances, significant and potentially hazardous exposures may occur from ingestion or dermal contact.

In the unlikely event that a small child finds a DDVP strip from a trap and chews on it, the routine exposure scenario, assuming 5 percent absorption, would result in a hazard quotient of 1-3. The possible consequences of such an exposure could be inhibition of acetylcholinesterase. For the extreme scenario, assuming 100 percent absorption, the hazard quotient would be 20-60, with resulting acetylcholinesterase inhibition (*fig. 4-1*).

For a child who finds and handles a DDVP strip, the hazard quotients would be 1 for a 1-minute exposure, 40 for a 1-hour exposure (the routine scenario), and 180 for a 4-hour exposure (extreme scenario). The 1-minute and 1-hour exposures would likely result in no effects; the 4-hour exposure may result in acetylcholinesterase inhibition.

Routine inhalation and dermal exposures to workers, which assumes proper handling of the DDVP strips, would result in negligible exposure and no health consequences. Inhalation that could occur from improper handling during indoor assembly (extreme scenario) would result in hazard quotients of 0.1-0.2, which also indicate no health consequences. Inhalation exposures that could occur while driving with the traps in an unventilated vehicle would result in hazard quotients of 0.6-1, indicating a possibility of acetylcholinesterase inhibition.

Dermal contact for a worker during assembly and placement of traps, assuming improper handling of the strips (extreme scenario) would result in a hazard quotient of 8, but no health consequences are anticipated.

Uncertainties

The risk from using DDVP is heavily influenced by the material used to contain the formulation. In this case, the release of DDVP is substantially retarded by the PVC matrix in which it is embedded. Human and animal data indicate that ingestion of DDVP contained in a PVC matrix is less toxic than ingestion of the same amount of DDVP not in a matrix. Information concerning release rates from the specific matrix used in gypsy moth projects is not available. Likewise, data regarding dermal absorption of DDVP contained in the specific PVC matrix used in gypsy moth projects are not available, although, data that are available suggest that dermal toxicity from exposure to a DDVP-PVC matrix is low (Zavon and Kindel 1966).

With the exception of marginal data on extreme exposure levels to the general public, the quality of the data supporting the remainder of the risk assessment can be categorized as being moderate to good (*table 4-1*).

Cumulative Effects

The only route of exposure to the general public is through tampering with traps. This is an unlikely event that probably would not recur for the same individual. Therefore, cumulative effects from the use of DDVP in traps is not anticipated to be a concern.

Workers, however, may be exposed repeatedly to DDVP. Some workers who are involved in assembly and placement of traps may be exposed to DDVP for several days. A tolerance to repeated exposures can be developed for some organophosphate insecticides (Gallo and Lawryk 1991); however, no such tolerance has been demonstrated for exposure to DDVP. Nevertheless, concern for repeated exposures of workers to DDVP during gypsy moth projects is low. The safety precautions taken by workers under normal handling conditions will not result in substantial exposure.

Carcinogenic risks are calculated on the basis of a total lifetime dose and were determined to be approximately four in 10 million for the highest oral exposure modeled. The risk of cancer is calculated to be directly proportional to the number of days of exposure. Therefore, if 1 day of exposure would result in a four in 10 million risk, then 5 days of exposure would result in a two in 1 million (twenty in 10 million) risk.

Connected Actions

No data are available on the effects of exposure to DDVP combined with exposure to the other treatment agents used in gypsy moth projects or to

the gypsy moth. Inhibition of acetylcholinesterase is the most sensitive effect of DDVP. No other agent used in gypsy moth control has this effect. Therefore, there is no basis for assuming that the effects of exposure to DDVP and any other agent will be additive. Other substances, including other organophosphate insecticides also inhibit acetylcholinesterase. Exposure to such compounds could lead to an additive effect with DDVP. In the unlikely event that the acetylcholinesterase activity in an individual is substantially depressed due to other compounds, that individual could be at increased risk if exposed to sufficient levels of DDVP.

Groups at Special Risk

Children are the group of primary concern from the use of DDVP in gypsy moth traps because they are the most likely to tamper with traps and be exposed to DDVP. Infants less than 6 months old have incompletely developed acetylcholinesterase systems and immature livers, although exposure of such an infant is extremely unlikely unless done through a purposeful act. Other groups known to have low blood acetylcholinesterase levels, and thus of special concern, include pregnant women, alcoholics, women taking birth control pills, individuals with advanced liver disease, long-distance runners, individuals with poor nutritional status, and individuals with skin diseases. Asthmatics may also be at special risk if DDVP induces or exacerbates respiratory distress (ATSDR 1993).

Effects Due to Disparlure in Mating Disruption

Two forms of disparlure are used in gypsy moth programs: the (+) and (–) enantiomers. The (+) enantiomer is the biologically active form, which is produced by the female gypsy moth to attract males. Racemic disparlure is a 50:50 mixture of the (+) and (–) enantiomers, and is used in mating disruption. The (+) enantiomer is used as a lure in gypsy moth traps which are used to monitor and delimit gypsy moth populations and for mass trapping treatments.

The female gypsy moth produces a pheromone that attracts males.

Hazard Identification

The toxicity of insect pheromones to mammals is relatively low (Jacobson 1977). Therefore, the U.S. EPA requires less rigorous testing of these products than it requires of insecticides (U.S. EPA 1994a), so that the toxicity data on disparlure is extremely limited.

A single oral dose of up to 34,600 mg/kg disparlure was not lethal to Sprague-Dawley albino rats (which means that the oral LD_{50} is greater than this) (Beroza and others 1975, Hercon 1978). No pathological changes were found in any of the treated rats. All of the animals exhibited hypoactivity, ruffed fur, and increased urination, however, the study did not include a control group.

Dermal toxicity testing of undiluted disparlure caused skin irritation after 24 hours of contact in rabbits, but no mortality was noted at rates up to 2,025 mg/kg, meaning that the dermal LD_{50} is greater than this (Beroza and others 1975, Hercon 1978).

Acute inhalation studies of disparlure in albino rats resulted in no mortality at an average aerosol concentration of 5.0 mg/L air for 1 hour (Hercon 1978), therefore the inhalation LC_{50} is greater than 5.0 mg/L.

In rabbits, 0.1 mL disparlure in the eye resulted in some redness of the conjunctiva at 24 hours, but no effects were observed 7 days after exposure (Beroza and others 1975, Hercon 1978).

After dermal contact disparlure persists in humans for extremely long periods of time. Some people who have come into contact with disparlure attract male gypsy moths for several years (Cameron 1981, 1983).

Exposure Assessment

A review of literature (Caro and others 1981, Plimmer and others 1978, Taylor 1982), indicated that an application rate of 30 g a.i./acre was estimated to result in concentrations of about 30 ng/m^3 of disparlure (1 ng equals one billionth of a gram).

Although the efficacy of disparlure depends on its volatility, 70-85 percent of disparlure may remain in the carrier matrix more than 30 days. Consequently, oral exposure may occur from consumption of disparlure flakes or tape. At an application rate of 30 g a.i./acre, an individual would have to consume all of the flakes in a 1 m^2 area to receive a dose of 7.4 mg. If this were done by a 10 kg child, the dose would be 0.74 mg/kg. When used in traps, each trap contains 0.5 mg of disparlure in a polymeric layer. A 10 kg child would have to eat the disparlure bait from 20 traps to get a potential dose of 1 mg/kg. The amount of disparlure released from the bait is unknown, thus the actual exposure could be less than 1 mg/kg.

Dermal exposures cannot be quantified. Based on the relationships summarized by Durkin and others (1995) and Rubin and others (1994), and on the molecular weight of disparlure (282.5), the estimated absorption rate for this compound is approximately 2.3 percent per day.

Dose-Response Assessment

The limited data available indicate that disparlure has a low order of acute toxicity, based on mortality as the endpoint:

- Oral LD_{50} greater than 34,600 mg/kg
- Dermal LD_{50} greater than 2,025 mg/kg
- Inhalation LC_{50} greater than 5 mg/L in 1 hour

Data regarding the toxicity of disparlure to animals or humans after subchronic or chronic exposures were not found in the available literature. Moreover, the acute toxicity of this compound for endpoints other than mortality is poorly characterized. Because of the limitations in the available data, a standard dose-response assessment was not done for disparlure.

Risk Characterization

Although exposure to disparlure is fairly well characterized, the lack of subchronic or chronic toxicity data precludes a quantitative assessment of risk (*table 4-1, fig. 4-1*). The available data regarding the acute toxicity of disparlure indicate that the potential hazard from exposure to the compound, whether from broadcast application or from its use in traps, is low. It must be noted, however, that disparlure is apparently long lasting in humans.

The only clear and unequivocal biological activity of disparlure is its ability to attract the male gypsy moth. Because disparlure is highly persistent, dermal contact with the compound might make an individual attract male moths for a long time. Although this is not likely to cause adverse health effects, it could be annoying.

Uncertainties

The reliance on acute toxicity data and the presumption that the toxicity of disparlure to mammals is low because it is an insect pheromone introduces uncertainties into the risk assessment that cannot be quantified. Other uncertainties in the analysis are associated with the exposure assessment and involve environmental transport and dermal absorption. These uncertainties are relatively minor compared with the lack of subchronic or chronic toxicity data.

Cumulative Effects

Little information is available on the toxicity of disparlure. As noted above, the ability to attract the male gypsy moth is the only clear biological activity of this compound. Since this compound seems to persist in humans for prolonged periods, repeated

exposures are more likely than single exposures to transfer sufficient quantities of disparlure to the individual to attract the moth. Again, while this may be a nuisance, it is not likely to be an adverse health effect.

Connected Actions

No information is available on the interaction of disparlure with other gypsy moth treatments or other chemicals commonly found in the environment. The interaction of disparlure with the adult male gypsy moth is obvious and substantial. Individuals who are exposed to sufficient quantities of disparlure and who live in an area with male gypsy moths will attract them. The definition of a sufficient quantity of disparlure, however, cannot be characterized with the available data.

Groups at Special Risk

The hazard identification for disparlure is essentially negative, that is, the toxic effects of disparlure, if any, have not been identified. Consequently, groups at special risk, if any, cannot be characterized. Because disparlure attracts the male gypsy moth, individuals who have an aversion to insects might be considered to be a sensitive subgroup. Nonetheless, this aversion and sensitivity would not be related to any obvious health effect.

Effects Due to the Sterile Insect Technique

The sterile insect technique involves the release of sterile gypsy moth pupae, or partially sterile pupae or egg masses into the treatment area. This technique results in an increase in gypsy moth numbers in the treatment area, so it is plausible that it would increase the chances of human contact with the gypsy moth.

Current thinking on the sterile insect technique is that it is best suited for gypsy moth populations less than 50 egg masses/ha (20 egg masses/acre) (Reardon and Mastro 1993). In an evaluation of egg release in Bellingham, Washington, in 1985 and 1986 an overflooding ratio of 34:1 of partially sterile egg masses to those estimated in the treatment area was used (Reardon and Mastro 1993). Taking

Two approaches to the sterile insect technique involve releasing gypsy moth pupae.

50 egg masses/ha as the upper limit of wild gypsy moth populations in a treatment area and releasing sterile or partially sterile insects in a 34:1 overflooding ratio, raises the potential gypsy moth population in the area to about 1750 egg masses/ha or 700 egg masses/acre. At that level there could be an increase in the number of skin rashes reported by people who spend time outdoors during the period of egg hatch and dispersal (ballooning) of the tiny gypsy moth caterpillars. The greatest prevalence of skin rashes may be in children (Tuthill and others 1984).

It is reasonable to expect that use of the sterile insect technique (primarily release of egg masses) could cause health effects similar to those described for exposure to moderate gypsy moth populations.

Summary of Effects

The quantitative risks to the general public from routine and extreme exposures to the gypsy moth and the treatments are displayed graphically in *figure 4-1*. The primary use of the information in the figure is to identify where effects are possible. To adequately complete the picture, however, it is necessary to examine the severity of those effects.

The information in this section summarizes the type and severity of effects that could result from exposure of the general public and workers to the gypsy moth and the treatments.

Gypsy Moth

Public

In moderate to heavy outbreaks, rashes or other adverse skin reactions could be prevalent, especially in children or other individuals who spend a substantial amount of time outside. Other irritant effects are plausible.

Workers

Although quantitative exposure assessments are not possible, the prevalence of individuals in the general population who are sensitive to the gypsy moth is sufficiently high to indicate that substantial numbers of workers exposed to the larvae could have irritation of the skin, eyes, or respiratory tract.

B.t.k.

Public

If exposed to the direct spray, some individuals are likely to have minor irritation of the skin, eyes, or respiratory tract. Pathogenic effects are not likely, even in immunocompromised individuals. Allergic responses, while conceivable, have not been documented.

Workers

Ground workers may have transient irritation of the eyes, skin, and respiratory tract unless effective methods are developed to reduce exposures. Aerial workers may develop such effects during prolonged periods of spraying.

Diflubenzuron

No clinically significant effects are likely for either the general public or workers, under either normal or extreme exposure assumptions. At high exposures, increases in certain blood pigments might be detectable. Highly conservative estimates of cancer risks are negligible, less than one in 1 million.

Gypchek

Public

Irritation of the eyes, skin, and respiratory tract is possible but the likelihood of such effects cannot be assessed because of limitations in the available toxicity and exposure data.

Workers

Irritation of the eyes, skin, and respiratory tract is more likely in workers than in the general public because exposure will be higher. As with the general public, the likelihood of such effects cannot be assessed.

DDVP

Under routine conditions, exposure and consequent risk to the general public and workers are negligible. In cases of tampering with or improperly assembling a trap, acetylcholinesterase inhibition is likely and signs of cholinergic toxicity are possible. Severe toxic effects are unlikely but cannot be ruled out. For short-term high-dose exposures, carcinogenic risks, while conceivable, cannot be well quantified.

Disparlure

Data are not sufficient for a quantitative risk assessment. By analogy to other insect pheromones, risks of toxic effects, if any, are likely to be slight for the general public and workers. Disparlure is very persistent on and in the body. Individuals exposed to disparlure may attract adult male moths for prolonged periods of time (that is, years). This may be a considerable nuisance. The level of exposure required to cause the attractant effect cannot be characterized, although the likelihood of this effect would seem greater for workers than for the general public.

Chapter 4, Part B
Ecological Effects

Contents

Part B Ecological Effects

This part of *chapter 4* describes the potential ecological effects that could be caused by the gypsy moth and gypsy moth treatments.

Before this environmental impact statement was prepared, comments were solicited from the general public and interested parties, to help identify and define the major issues to be addressed. Some of the issues were ecological, including potential adverse effects to nontarget organisms, forest condition, water quality, and soil. Based on these and other environmental concerns, an ecological risk assessment was undertaken.

This part summarizes the Ecological Risk Assessment. For more information on the methods used and results of the Ecological Risk Assessment, see *appendix G*, which is a separate volume.

Methods

Ecological risk assessments are usually prepared for projects of limited geographical scope and examine impacts to a few nontarget species or other components of the environment that are of particular value to people, for example, a high value timber stand, a scenic vista, or a prized trout fishery. These valued components of the environment are called endpoints.

The endpoints selected for evaluation were those that can alter the function or structure of an ecosystem:

- Change in numbers of nontarget species or the size of their populations
- Change in forest condition
- Change in water quality
- Change in microclimate
- Change in soil fertility or productivity.

These endpoints are broad and not easily measured. Therefore, each endpoint is also associated with a set of ecological indicators (*table 4-2*). These indicators are aspects of the endpoints that can be measured and for which some information is available in the literature. Special attention was given to choosing indicators that might affect plant and animal populations rather than individuals because consequences to individual plants or animals may not be ecologically meaningful. When responses of the indicators to the gypsy moth or treatments are examined collectively, they provide a reliable basis for assessing the response of consequences to the endpoint.

Hazard Identification

For the Ecological Risk Assessment, the potential effects of the gypsy moth and treatments on the five endpoints, through their indicators, were determined primarily through an extensive review of the literature.

Exposure Assessment

To determine the extent to which the five endpoints are likely to be exposed to "stressors," that is, the treatments and the gypsy moth, it was necessary to estimate the following: where the stressors go in the environment and how they get there (fate and transport), how much of them is present and for how long, which environmental components or organisms could be exposed to them, and any uncertainties associated with deriving these estimates. The exposure assessment was accomplished by using existing data, computer models, and various statistical techniques.

For *B.t.k.*, gypsy moth nucleopolyhedrosis virus, and the mating disruptant disparlure, no single environmental factor that has a primary effect on fate and transport was identified. An important factor in the fate and transport of diflubenzuron was identified—the density of human development. In other words, the overall difference in fate and transport of diflubenzuron varies more between developed and undeveloped forested areas than among forest types.

Table 4-2. Ecological endpoints and their indicators

Endpoints	Indicators
Change in nontarget species number or population densities	• Number of species of mammals, birds, reptiles, amphibians, fish, invertebrates. • Population densities of groups of special concern: spring- and summer-emerging native lepidopterans, insect predators and parasites, pollinators, amphibians, mollusks. • Population densities of organisms eaten by game fish: crustaceans, aquatic insects, small fish.
Change in forest condition	• Forest productivity, tree growth rates, mast production. • Successional state, stand age, species composition of trees and understory vegetation. • Susceptibility to fire. Incidence of disease, tree mortality rates, degree of insect damage.
Change in water quality	• Water temperature, dissolved oxygen concentration. • Nutrient concentration, algal densities. • Flow rate, water yield, and sediment load. • Detrital decomposition rate.
Change in microclimate	• Percent defoliation, amount of light penetrating the tree canopy, soil and litter temperature, relative humidity below the canopy.
Change in soil fertility or productivity	• Population densities of organisms that alter soil composition or texture: litter invertebrates, earthworms, bacteria, and fungi. • Litter production, concentration of organic material, decomposition rate, soil pH, erosion rate.

Risk Characterization

Where sufficient data were available to support it, a quantitative risk characterization was performed. Otherwise, risk characterizations were qualitative. In the Ecological Risk Assessment, quantitative risk characterizations were conducted only for the effects of *B.t.k.* and diflubenzuron on nontarget organisms. Qualitative risk characterizations were conducted for all other topics examined, including the other four treatments.

The primary method used for evaluating risk to nontarget organisms from exposure to diflubenzuron was a screening index. This index compared the results of the exposure assessment with an established toxicological benchmark value that was adjusted with a safety factor (Urban and Cook 1986). If the screening index exceeded one for any group of organisms, then the group was considered to be at risk of mortality.

Environmental residues and toxicolgical responses of nontarget organisms and gypsy moth life stages to diflubenzuron can vary depending on a number of factors. To account for the sources of variability, a Monte Carlo simulation of the screening index was conducted (Spain 1982). This computer model uses randomly selected values from frequency distributions for toxicological benchmarks and environmental parameters used to calculate the

resulting environmental concentrations of diflubenzuron. When the probability of mortality was 1 percent or greater, further statistical analyses were conducted through another Monte Carlo simulation combining probit analysis (Finney 1971) and the estimated environmental concentration of diflubenzuron. These analyses estimated the probability of at least 50 percent, at least 75 percent, and at least 90 percent reductions in nontarget populations. An estimate of mean population reduction was also calculated.

The limited information available for *B.t.k.* made it more difficult to calculate a quantitative estimate of risk of mortality. Most of the existing toxicological studies did not report an exact dose of *B.t.k.* that must be consumed for death to occur. A single *B.t.k.* crystal, if ingested by a susceptible caterpillar during a susceptible instar, can cause death. Rather than calculate the risk of mortality, the probability of encountering a *B.t.k.* drop was calculated. Many lepidopteran species are not affected by *B.t.k.*, however, and some that are affected may even complete their development and emerge as reproducing viable adults. Thus the risk of encountering a *B.t.k.* drop probably overestimates the risk of mortality to some lepidopterans.

Effects Due to the Gypsy Moth

Hazard Identification

The ecological effects of gypsy moth and its feeding on the vast hardwood forests of the eastern United States continue to be extensively studied, and are summarized in this section. The resource impacts that occur during and after gypsy moth outbreaks are influenced by a number of physical and biological factors. These impacts may be dramatic, yet often prove to be variable and hard to predict. This is, in part, because past stand conditions and health—like prior defoliation, drought, and other stresses—play a large role in determining how individual trees and forest stands react to physical and biological factors.

Entire stands or forests may be defoliated during outbreaks.

The applicability of the information in this section to individual hardwood trees and stands in the western United States is not known, but it seems prudent to assume that susceptible western species will be affected similarly to those in the East. The same may be said for nontarget organisms, forest condition, water quality, microclimate, and soil productivity and fertility. This assumption is likely to be true in areas of extensive oak forests and stands such as those in western Texas and California. In smaller noncontiguous hardwood stands, effects might differ. In such stands establishment of the gypsy moth could have an adverse effect on native moth and butterfly species, if they compete for the same limited food sources.

Effects on Vegetation

During intervals between outbreaks, gypsy moth caterpillars usually eat only a small proportion of even their most favored host species. When defoliation is low, nearly all feeding occurs on the most favored hosts, such as oaks (Campbell and Sloan 1977a). Once an outbreak is underway the list of plants the caterpillars feed on expands to include some 300 species of broadleaved and coniferous trees and shrubs (Leonard 1981). This list grows even longer as the insect invades new areas (*app. D*, Plant List).

Ecological Effects

Growth Loss

Though estimates vary, trees stripped of 50 percent or more of their leaves are likely to refoliate during the same season. The new leaves are fewer and smaller than the originals, and repeated defoliation can cause additional reductions in leaf size (Wargo 1981a). Twig and branch dieback may occur in addition to significant sprouting from adventitious and latent buds (Staley 1965). Crown dieback and loss of buds adversely affects production of flower buds and acorns for a period of time during and after defoliation. During moderate and heavy defoliation acorns may even be aborted to conserve starch reserves for growth and survival (Gottschalk 1990b). Many small feeder roots die after defoliation. This loss of feeder roots reduces water and mineral uptake, which can slow tree recovery (Wargo 1978b). The effects of a single heavy defoliation in a mixed stand of oaks in eastern New England were visible for 10 years before the trees returned to their predefoliation condition (Campbell and Sloan 1977a).

In southern New England, decreases in stem volume growth averaged about 20 percent in any year a tree was defoliated compared with the previous undefoliated year (Twery 1987). Chestnut oak was most affected, averaging growth loss of 33 percent, while some individual trees suffered decreases in volume growth of 50-65 percent. Growth loss in trees may be evident up to 3 years after defoliation (Twery 1987, Wargo 1981a). For a 2-year defoliation episode the average reduction in volume growth of individual trees was 9.7 percent per year for the stand over a decade (excluding mortality) (Twery 1987).

Growth losses described for individual trees may not manifest themselves at the stand level. Stand growth depends on kinds of trees in the stand, the variety of tree sizes, and whether the trees are using all the resources available on the site. Stand growth may or may not be affected by defoliation and mortality of individual trees. Loss of trees with no commercial value may actually improve the growth of the remaining stand through a thinning effect, or a decrease in growth in an immature stand may be partially recovered by the resulting delay before competitive crowding occurs (Twery and Gottschalk 1988). Oaks that were not defoliated actually grew better than average during the year that neighboring oaks were defoliated (Twery 1987). Trees that grow more slowly because of defoliation occur across all timber stands contributing to decreased volume growth (Gansner and Herrick 1982, Herrick and Gansner 1988). Over time, however, losses in volume growth apparently are recovered as trees respond to and fully utilize the available growing space (Gansner and others 1993b).

What happens when a tree is defoliated depends on five key factors: (1) how much foliage is removed; (2) the number of successive years of defoliation; (3) when in the growing season the defoliation occurs; (4) the presence and number of secondary organisms present; and (5) the physiological condition of the tree at the time of defoliation (Parker 1981). Trees already under stress, such as from drought or other factors, often succumb more quickly to the effects of defoliation than do trees in a healthier condition.

The adverse effects of defoliation are due primarily to the reduction of carbohydrate (starch) production and the use of stored starch reserves (Heichel and Turner 1976, Kozlowski 1969). These physiological changes weaken trees and make them vulnerable to attack by secondary organisms, which can cause further decline and death. In the eastern United States the principal secondary organisms are the shoestring fungus (*Armillaria mellea* [Vahl ex. Fr.] Kummer [*Armillariella mellea* (Vahl ex. Fr.) Karst]), and the twolined chestnut borer (*Agrilus bilineatus* [Weber]) (Houston 1981a, Wargo 1981b). Most trees can tolerate 2 years of defoliation before root starch reserves are depleted (Wargo 1981a).

Mortality

Several factors interact to produce tree and stand mortality: severity, frequency, and distribution of defoliation; site and stand factors; environmental conditions; tree vigor; and presence and abundance of secondary organisms (Campbell and Valentine 1972, Kulman 1971, Staley 1965, Wargo 1978a,b). Because so many factors affect mortality, it varies from stand to stand, even when stands have similar characteristics. Mortality may be 80-100 percent on some stands (Campbell and Sloan 1977a, Gansner and Herrick 1984). Such extensive mortality,

however, is the exception rather than the rule. The first time the gypsy moth defoliates an area, 15–35 percent mortality can be expected. Results to date support the conclusion that most mortality occurs during and after the initial outbreak (Twery 1991). In a general way the pattern of the most severe tree mortality occurring along and behind an advancing outbreak front has been repeated as gypsy moth invaded new areas (Gansner and Herrick 1984, Herrick and Gansner 1986a, Twery and Gottschalk 1988).

The most useful variables for predicting stand mortality after gypsy moth defoliation appear to be stand composition, duration of defoliation, and defoliation intensity (Fosbroke and Hicks 1989). Oaks and other susceptible species have more severe and frequent defoliation and, as a result, higher mortality than do nonsusceptible species (Campbell and Sloan 1977a; Herrick and Gansner 1987; Quimby 1985, 1987). Moderate defoliation (30-60 percent) increases mortality slightly, and heavy defoliation (more than 60 percent) increases it even more (Campbell and Valentine 1972, Gottschalk 1989). As the frequency of defoliation increases so does mortality (Campbell 1979, Feicht and others 1993).

After 1–3 years of defoliation, trees may begin to die.

Tree condition at the time of defoliation also influences mortality. Trees with poor crowns are more likely to die from a defoliation event compared with trees with good crowns. This relationship between crown condition and mortality after defoliation has been observed frequently (Gansner and others 1978, Gottschalk and MacFarlane 1993, Herrick 1982, Herrick and Gansner 1987, Tigner 1992).

A few generalizations can be made about how site and stand conditions affect mortality. Defoliation tends to be the most severe on poor sites. Tree mortality tends to be higher on moister, better sites (Crow and Hicks 1990, Gansner 1987, Hicks 1984), which is not to say that high mortality cannot be found on poor sites.

Drought may influence the severity of gypsy moth effects on trees (Bess and others 1947, Campbell and Sloan 1977a, Stephens and Hill 1971). If severe drought occurs with repeated years of defoliation, the cumulative impacts may increase mortality. Stress from disturbances, such as timber cutting or fire, and naturally occurring oak decline can also influence mortality. Oak decline causes reduced growth, crown dieback and, after several years, mortality in susceptible trees. Declining oaks are more vulnerable to mortality after defoliation; and healthy oaks, when defoliated, are predisposed to decline (USDA Forest Service 1994f).

Stand Structure and Composition

Stand structure (the variety of tree sizes) is affected by defoliation and subsequent mortality. Subdominant trees typically have much higher mortality rates than dominant trees after heavy defoliation (Campbell 1979, Gansner and others 1993c, Quimby 1993). One typical result of heavy and repeated defoliation is a more one-storied stand. The volume of small diameter oak trees may actually decrease, but these losses are offset by gains in larger trees (Gansner and others 1993a). Changes in stand structure range from an effect much like an intentional thinning from below which removes smaller trees (Campbell and Sloan 1977a, Gottschalk 1990b); to heavier losses of larger trees that create scattered gaps in the canopy; to an almost completely open canopy as mortality increases (USDA Forest Service 1994f). An intentional thinning from below in oak stands tends to enhance acorn production, production of high quality logs, growth in larger trees, and to improve esthetic qualities of the stand due to the presence of large trees.

Significant changes in the vegetation composition of a stand may also occur. After gypsy moth outbreaks many investigators have noted increases in red maple (*Acer rubrum* L.) and other species, and corresponding decreases in oak in Appalachian forests (Allen and Bowersox 1989; Gansner and others 1994, In press; Hix and others 1991). Commonly, moderate to heavy defoliation accelerates forest succession towards more shade-tolerant (and less defoliation-prone) species (Campbell and Sloan 1977a, Clement and Nisbet 1972, Feicht and others 1993, Houston 1981b, Stephens and Hill 1971).

The long-term trend is toward stands with less oak and more species not preferred by the gypsy moth. Oak will still be present, however, and may be a major component in many stands, especially on lower quality sites. Trends in New England and Pennsylvania have been an average shift in composition towards less oak, with some stands having major losses and others having only minor changes (USDA Forest Service 1994f). While oak stands farther to the south and west in the Appalachian region may have different characteristics, trends there may be similar to those in New England and Pennsylvania.

Seed and Mast Production

Seed production by defoliated oak trees is reduced directly through consumption of oak flowers and young acorns by gypsy moth caterpillars, and indirectly by abortion of acorns and reduced initiation of flower buds in the years after defoliation (Gottschalk 1990b). These effects are generally short-lived with residual effects lasting for 1 or 2 years after defoliation ends. Abortion of immature acorns appears to be the most significant of these three effects, and up to 5 years of complete acorn failure is possible (Gottschalk 1990b).

Uninterrupted feeding by caterpillars is typical during outbreaks.

Mortality of oaks and their replacement by other species will also reduce acorn production. Significant mortality (more than 60 percent of basal area in a stand) of oaks must occur before acorn production is reduced significantly (Gottschalk 1990b), because much of the initial oak mortality is predominantly nonproducing trees.

Nuts, seeds, and fruits that serve as food for animals in the forest are called mast. Over the long term an increase in soft mast (such as berries) partially compensates for the loss of hard mast (such as acorns) (Gottschalk 1990a).

Other Effects on Vegetation

Gypsy moth defoliation and tree mortality affect stand regeneration and understory vegetation in several ways. Besides the loss of acorn production, stump sprouts of susceptible species can be heavily defoliated and die just as overstory trees can (USDA Forest Service 1994f). Stump or stem sprouts are a major source of regeneration, which increases in importance for oaks on poorer sites and in younger stands. When oaks and other susceptible trees die after defoliation they usually do not sprout, especially if they have been infected with shoestring fungus which kills the roots (Gottschalk 1988).

The most common response to the canopy gaps created by tree mortality is increased growth and density of existing understory woody plants (Collins 1961, Ehrenfeld 1980, Feicht and others 1993, Hix and others 1991). Herbaceous plants will also rapidly expand their density and coverage (Gottschalk 1988). Heavy defoliation and significant mortality that create wide-spread canopy openings may hasten the establishment of new plants (USDA Forest Service 1994f). In some areas that are subject to intense deer browsing, trees may fail to regenerate and shrubs or herbaceous plants can dominate (Gottschalk 1988).

Heavy defoliation from the gypsy moth increases fire danger, although differences in fuels have not been measured nor has the increased fire

hazard been calculated (Gottschalk 1990a). An abundance of heavy fuel, standing dead snags, dense understory vegetation, and numerous fallen trees act in combination to promote spot fires, impede fire line construction, and extend the time needed for post-fire mopup operations, such as felling snags and trenching logs (Tigner 1992).

Effects on Terrestrial and Aquatic Animals

The Ecological Risk Assessment examined gypsy moth impacts on selected mammals, birds, reptiles and amphibians, native lepidopterans, other terrestrial and aquatic invertebrates, fish, and mollusks and crustaceans.

Mammals

The gypsy moth has varying effects on mammals. In black bear (*Ursus americanus* Pallas) for instance, cub production and adult and subadult survival rates did not appear to be affected by defoliation, acorn crop failures, or tree mortality in Shenandoah National Park (Vaughan and Kasbohm 1993). Despite shifts in seasonal habitat preference and fall foods, the gypsy moth had little effect on black bear.

Other mammals respond differently, with gray squirrel (*Sciurus carolinensis* Gmelin) possibly being the most adversely affected due to its dependence on the acorn crop (Silvester 1991). Populations of white footed mouse (*Peromycus leucopus* [Rafinesque]), which is an important predator of gypsy moth caterpillars and pupae, may be affected in the spring by the size of acorn crops the previous fall (McShea and Rappole 1992, McShea and Schwede 1993), as well as by high populations of white-tailed deer (*Odocoileus virginianus* [Zimmermann]) that compete for mast. Generally, white-tailed deer respond positively to forest changes caused by heavy defoliation due to their need for dense brush and seedlings (DeGraaf and others 1992).

Bats are a concern, but the effect of defoliation and tree mortality on them is not well known. Tree mortality will create additional cavities for bats to use (DeGraaf and others 1992). Because the endangered Virginia big-eared bat (*Plecotus townsendii virginianus* Handley) feeds on insects—primarily moths, which compete with the gypsy moth for food—it may be affected by the gypsy moth (Sample and Whitmore 1993, Sample and others In press).

Birds

Defoliation appears to have positive impacts, both short and long term, on most nongame birds (Cooper and others 1987, Thurber 1992). Overall bird density and number of species increase. Among game birds, heavy defoliation strongly favors ruffed grouse (*Bonasa umbellus* [Linnaeus]) by creating understory conditions needed for nesting, feeding, and courtship (Johnsgard 1989) and appears to have little long term effect on wild turkey (*Meleagris gallopavo* Linnaeus) (Wunz and Pack 1992). While temporary effects may be noted in neotropical migrants, there should be no long term effects caused by gypsy moth (Cooper and others 1994).

Heavy defoliation creates habitat for ruffed grouse.

Reptiles and Amphibians

The short-term increases in exposure to sunlight resulting from defoliation are expected to degrade surface habitats of reptiles and amphibians (DeGraaf and others 1992). In the long term reptiles and amphibians, especially salamanders, are expected to benefit from more dead and downed trees (DeGraff and others 1992). The timber rattlesnake (*Crotalus horridus* Linnaeus) is expected to be affected by similar short term impacts (Peterson 1990).

Long-term effects on the rattlesnake depend on the ability of the resulting plant community to support small mammals that the snake eats.

Native Lepidopterans

Little information is available on the impacts of gypsy moth defoliation on native lepidopterans. While competition for food will eventually affect the inferior competitors (Gause and Witt 1935, Hutchinson and Deevy 1949), gypsy moth and other lepidopterans increase in number together (Schweitzer 1988). In the long term, species requiring oak-dominated forests will probably decline while others may increase as a result of the increase in plant species that often follows gypsy moth outbreaks.

Few spring-emerging moth and butterfly caterpillars hatch as late and grow as slowly as gypsy moth caterpillars (Schweitzer 1988). Therefore, the majority of these species should finish their feeding activity before gypsy-moth-caused defoliation is severe enough to bring a risk of starvation. This is not the case for summer-emerging caterpillars that feed on many of the same hosts as the gypsy moth and may starve during outbreaks.

Other Terrestrial Invertebrates

Diverse invertebrate groups, such as beetles, flies, wasps, various pollinators, earthworms, spiders, and other litter- and soil-inhabiting invertebrates, may show some short-term loss in numbers due to defoliation and subsequent tree mortality. In the long term, however, gypsy moth outbreaks will probably lead to more species of invertebrates due to more species of plants.

Fish

Heavy gypsy moth defoliation has been shown to cause an increase in water temperature (Sheath and others 1986) and a decrease in a stream's capacity to neutralize acids (Downey 1991). These factors could make some marginal streams uninhabitable for brook trout (*Salvelinus fontinalis* Mitchill) (Downey and others 1994) in the short term, but large-scale failures of trout populations are not likely. Increased nutrient supplies resulting from defoliation may result in a short-term adverse effect on other fish.

Effects on Water Quality, Microclimate, and Soil Productivity and Fertility

The Ecological Risk Assessment examined gypsy moth impacts on water quality, microclimate, and soil productivity and fertility.

Water Quality

Defoliation by the gypsy moth may affect a number of characteristics of water bodies, including temperature, flow rate and yield, sediment load, acidity levels, oxygen availability, nutrient concentration, and structural habitat for aquatic organisms.

Defoliation along woodland streams may change water quality.

Defoliated riparian areas receive increased exposure to sun. Increases in the amount of light penetrating stream surfaces and changes in water temperature can affect both plants and animals in the stream. Various factors influence stream temperature at a given point, including flow volume, hydraulic gradient, ground water discharge, degree of shading, and upstream conditions. Actual changes to water temperature will vary from site to site and will depend in part upon the degree and duration of defoliation (USDA Forest Service 1994f). On a headwater stream under a dense tree canopy light penetration increased from 5-18 percent to 73 percent after a "massive" gypsy moth outbreak in Rhode Island (Sheath and others 1986). Water temperature increased by 3.7 degrees C (6.7 degrees F) in early July, and algal growth in the stream bed increased dramatically.

Defoliation by the gypsy moth has been shown to increase water yield (Corbett and Lynch 1987), in part due to fewer leaves being available to transpire moisture from the soil (Twery 1991). Increased water yields from forested watersheds may produce beneficial results, such as creating more wet areas during summer, which might enhance habitat for amphibians. On the other hand, increased stream discharge may have a destabilizing effect on herbivorous insects (Eagle 1993).

Normal sediment loads from forested land are low; however, increases in stream velocities due to increased water yield could possibly lead to increased erosion, sedimentation, and turbidity. Timber cutting, exclusive of disturbances caused by road construction and log removal, usually has little if any effect on stream turbidity and sedimentation (Corbett and Lynch 1987). Therefore, gypsy moth defoliation would be unlikely to cause an increase in watershed erosion.

Whenever defoliation by the gypsy moth causes tree mortality in riparian areas, the structural habitat of streams may be altered by deposition of woody debris in affected streams. Debris dams may trap more organic material, lengthening the time it is available for ingestion by benthic invertebrates and leaf shredders, and allowing for more complete energy utilization. Large woody materials also provide improved fisheries habitat (USDA Forest Service 1994f).

Defoliation by the gypsy moth may contribute to alterations in water chemistry and a reduction in the capacity to neutralize acids in some streams associated with upland watersheds in the southern Appalachian region (USDA Forest Service 1994f). Acid neutralizing capacity determines the concentrations of hydrogen and aluminum in solution, which at elevated levels are toxic to fish and other aquatic organisms. Acid neutralizing capacity of streams increases seasonally, when deciduous leaves are present in the tree canopy. Defoliation temporarily produces conditions typical of winter, that is, reduced acid neutralizing capacity and increased acidity (Downey 1991).

Increased organic matter in streams from gypsy moth frass and leaf fragments, in combination with increased light penetrating the water's surface, may lead to over-enrichment and result in excessive growth of algae and other microorganisms. This bloom could cause a reduction in oxygen available to other organisms in the stream. Large increases in fecal coliform and streptococci densities have been observed in streams where heavy gypsy moth defoliation has occurred (Corbett and Lynch 1987).

Defoliation is also suspected of causing increased nitrate mobility. Elevated concentrations of nitrate in streams have been associated with forest harvest (Vitousek and Melillo 1979) and defoliation by insects (Swank and others 1981, USDA Forest Service 1994f). Defoliation by the gypsy moth can accelerate the transfer of nutrients from vegetation to the soil surface; however, there is little evidence that these nutrients are lost from the site and enter adjacent water bodies to a significant degree (Eagle 1993, Grace 1986).

Microclimate

The microclimate of defoliated areas is affected by rises in soil, leaf litter, and ambient air temperatures due to increased exposure to sunlight (Vaughan and Kasbohm 1993). Coupled with increases in soil moisture and nutrient content, these temperature increases could result in increased understory growth (Tomblin 1994).

Soil Productivity and Fertility

Gypsy moth defoliation will probably increase the rate of decomposition of organic matter due to

increased exposure to sunlight, temperature, and nutrient levels in the forest litter (Grace 1986). Removal of tree canopy in areas of heavy defoliation should not result in increased erosion because of the presence of understory, which is usually not removed by the gypsy moth.

Exposure Assessment

The intensity and duration of a gypsy moth outbreak and the interval between outbreaks are critical determinants of subsequent ecological effects. An analysis of potential exposure of ecosystems to the gypsy moth and defoliation is largely a matter of assessing probable duration of an outbreak and the interval between outbreaks. Attempts to predict multiyear trends in gypsy moth outbreaks have thus far yielded unsatisfactory results. Gypsy moth management decisions for the coming year are based on population and defoliation trends for the current year (estimated from egg mass counts) together with information about prior outbreak duration. Therefore, risks were analyzed for three levels of defoliation lasting for one, two, or three successive years. The levels of defoliation were light (less than 30 percent defoliation), moderate (30-60 percent defoliation), and heavy (more than 60 percent defoliation).

Once an area becomes generally infested by the gypsy moth, it is assumed that the area will support at least a few gypsy moths every year if suitable host trees are available. As long as gypsy moth populations remain low, effects are minor. Light defoliation is representative of the normal and usually hard to detect background defoliation that occurs in low or innocuous gypsy moth populations. This background defoliation is assumed to occur annually. Outbreaks, on the other hand, occur periodically and often are unpredictable. Moderate and heavy defoliation are assumed to occur for 1 to 3 successive years during an outbreak. During this period significant environmental effects occur. Defoliation subsides to background levels (light defoliation) after an outbreak.

Risk Characterization

This section presents a summary of the likely effects on the endpoints due to three levels of defoliation: light (less than 30 percent), moderate (30-60 percent), and heavy (more than 60 percent). Read this risk characterization in conjunction with *tables 4-3* and *4-4*, which show projected short- and long-term responses of 56 ecosystem components to moderate and heavy defoliation.

Light Defoliation

Nontarget Organisms

Natural enemies of the gypsy moth may be nontarget organisms. In the absence of outbreaks, the arrival of the gypsy moth will result in an increase in the numbers of certain natural enemies of the insect, such as the nucleopolyhedrosis virus, parasitoids, and entomophagous fungi. Changes in other faunal groups, if any, will be too subtle to measure.

Forest Condition

In any forest, foliage-eating insects are always present and all trees are likely to lose some of their foliage every year. Because leaves are among the tissues that plants are most capable of replacing, no change in forest condition is expected.

Water Quality, Microclimate, and Soil Productivity and Fertility

No detectable changes are anticipated in water, microclimate, or soil, due to light defoliation caused by the gypsy moth.

Moderate Defoliation

Nontarget Organisms

Changes in nontarget organisms are expected as a result of changes in habitat and availability of food after moderate defoliation. Short-term responses by nontarget organisms should include increases in gypsy moth parasites and predators, and possible

Table 4-3. Changes in ecosystem components after a moderate gypsy moth outbreak

		Moderate defoliation (30 - 60 percent) for. . .					
		1 year		2 years		3 years	
Ecosystem component[1]	Confidence	Short Term	Long Term	Short Term	Long Term	Short Term	Long Term
Trees							
Condition R	High	–[2]	0	–	0	–	0
Mortality R	Intermediate	0	0	+	0	+	0
Diversity D	Intermediate	0	0	0	+	0	+
Pathogens A	High	0	0	+	0	+	0
Diameter growth R	High	0	0	–	0	–	0
Volume changes R	High	0	0	–	0	–	0
Shrubs A	High	0	0	+	0	+	+
Herbaceous cover A	Intermediate	0	0	+	0	+	+
Hard mast A	High	0	0	–	0	–	0
Soft mast A	Low	0	0	+	0	+	0
Fire hazard R	Low	0	0	0	+	0	+
Gypsy moth natural enemies A	High	+	0	+	0	+	0
Mammals D	Intermediate	0	0	0	0	0	+
Bats A	Low	0	0	0	0	0	0
Black bear A	Intermediate	0	0	0	0	0	0
White-tailed deer A	Intermediate	0	0	0	0	0	+
Gray squirrel A	High	0	0	–	?	–	?
Deer mouse A	Intermediate	0	0	–	?	–	?
Birds D	High	0	0	0	+	0	+
Wild turkey A	Intermediate	0	0	0	0	0	0
Ruffed grouse A	Intermediate	0	0	0	0	0	+
Neotropicals A	Intermediate	0	0	0	0	0	0
Reptiles and amphibians D	Low	0	0	–	0	–	0
Timber rattlesnake A	Intermediate	0	0	0	0	–	0
Amphibians A	Intermediate	0	0	–	0	–	+
Fish D	Low	0	0	0	0	0	0
Stream-using salmonids A	Low	0	0	–	0	–	–
Other game fish A	Low	0	0	0	0	0	0
Invertebrates D	Intermediate	0	0	0	0	0	+
Native lepidopterans D	Intermediate	0	0	0	0	?	0
Spring lepidopterans A	Intermediate	0	0	0	0	?	0
Summer lepidopterans A	Low	0	0	0	0	?	0
Litter invertebrates A	Low	+	0	+	0	+	0
Insect parasites and predators A	Intermediate	0	0	–	0	–	+
Spiders A	Intermediate	0	0	+	0	+	0
Pollinators A	Intermediate	0	0	0	+	0	+
Aquatic insects A	Low	+	0	+	0	+	0
Earthworms A	Intermediate	0	0	+	0	+	0
Mollusks A	Low	0	0	–	0	–	?
Crustaceans A	Low	0	0	–	0	–	?
Detrital decay rate R	Low	+	0	+	0	+	0
Algal density A	Low	0	0	+	0	+	0

(continued next page...)

Table 4-3. Continued

Ecosystem component[1]	Confidence	Moderate defoliation (30 - 60 percent) for. . . 1 year Short Term	1 year Long Term	2 years Short Term	2 years Long Term	3 years Short Term	3 years Long Term
Water							
Temperature A	Intermediate	0	0	+	+	+	+
Dissolved oxygen A	Low	0	0	–	0	–	0
Nutrients A	Low	0	0	+	0	+	0
Flow rate R	Intermediate	+	0	+	0	+	0
Yield A	Intermediate	+	0	+	0	+	0
Sediment load A	Low	0	0	0	0	+	0
Microclimate							
Soil-litter temperature A	High	+	0	+	0	+	0
Light below canopy A	High	+	0	+	0	+	0
Relative humidity below canopy A	High	–	0	–	0	–	0
Soil							
Decomposition rate R	Intermediate	+	0	+	0	+	0
Litter production A	Intermediate	0	0	0	0	0	0
Quantity organic matter A	Intermediate	+	0	+	0	+	0
Soil pH R	Low	0	0	0	0	0	0
Erosion rate R	Intermediate	0	0	0	0	0	0

[1] R = rate or appearance
D = diversity
A = abundance or quantity

[2] – = expected decrease
0 = no expected change
+ = expected increase
? = uncertainty

increases in numbers and types of birds; however, some species, such as flycatchers, may decline (*table 4-3*). Gray squirrel numbers will probably decline, as may various amphibians. Increases in water temperature could cause short-term increases in aquatic insects, but some marginal streams may lose trout populations. There may also be minor decreases in numbers and types of other insects, particularly lepidopterans.

In the long term, 2 or 3 consecutive years of moderate defoliation could increase or decrease numbers of gray squirrel and white-footed mouse, depending on long-term survival rates and mast-producing capability of dominant oaks. Numbers of nongame bird species may increase, but neotropical migrants may not be affected. Salamander populations should benefit from increases in dead and downed material. The numbers and types of pollinators and other insects may increase in response to a more diverse plant community.

Forest Condition

Short-term impacts of moderate defoliation on forest condition will be slight. Tree condition may begin to deteriorate, wood production in susceptible trees may decline, and growth of understory vegetation may increase. Production of acorns (hard mast) will be reduced and may continue to be low for as many as 5 years. Production of berries and other soft mast may increase.

If an area is defoliated only 1 year, long-term effects will be minimal and difficult to measure. After 2 or more years of moderate defoliation, some of the shorter trees will begin to die, and the stand will become more one-storied. Tree species favored by the gypsy moth will probably decline, and less-favored species will increase. Successional changes over time to more shade-tolerant species, such as red maple, will be accelerated. Hard mast production will return to predefoliation levels. The stand as a whole will probably be less susceptible to future gypsy moth defoliation.

Water Quality

Some slight short-term increases in water temperature and yield, and decreases in dissolved oxygen may result from moderate defoliation.

Few long-term effects should result. Sustained moderate outbreaks may result in a slight decade-long (or longer) seasonal increase in water temperature in small streams bordered by susceptible vegetation. Some additional woody debris might be deposited in streams.

Microclimate, and Soil Productivity and Fertility

Moderate defoliation should result in seasonal increases in soil and litter temperatures, as well as increased exposure to sunlight. These changes should result in short-term increases in biological productivity on the forest floor.

No long-term changes in microclimate or soil productivity and fertility are expected after moderate defoliation.

Heavy Defoliation

Nontarget Organisms

Short- and long-term effects of heavy but not complete defoliation on nontarget organisms will probably be similar to those of several years of moderate defoliation. Even 1 year of complete defoliation, however, will have dramatic effects on Lepidoptera, which could suffer large-scale starvation (Schweitzer 1995).

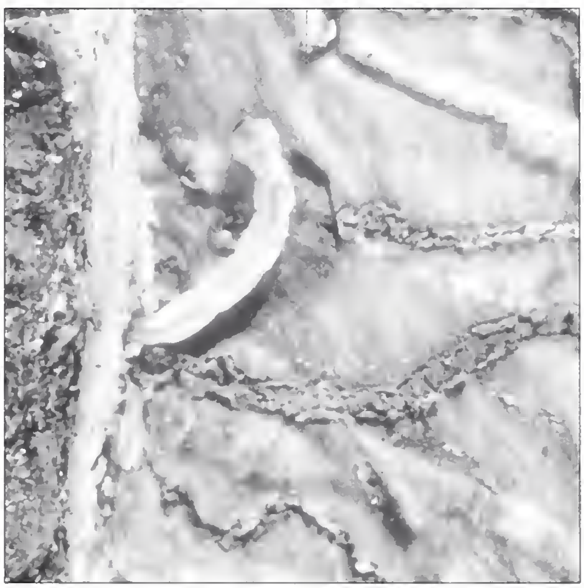
Short-term impacts of 2 or more years of heavy defoliation will be dramatic. Gray squirrel numbers and productivity will probably decline. Numbers of some birds will decline, but others, such as woodpeckers, may increase. Small mammals and possibly timber rattlesnakes may decline, as may amphibians such as salamanders. Trout may also decline or disappear from small streams, as may small stream-dwelling crayfish and snails. Forest-feeding lepidopterans, particularly those that feed on oaks, and their parasitoids will probably decline. Other forest-dwelling invertebrates may also decline. Gypsy-moth-specific parasitoids will increase significantly. Bear, turkey, and bats will probably begin feeding on the gypsy moth but may migrate to undefoliated or less defoliated areas. White-tailed deer will probably move to undefoliated areas. Grouse and turkey may have an increase in nesting failures.

In the long term, gray squirrels and possibly trout might be reduced or eliminated from defoliated areas for years. Other nontarget organisms will either increase or remain at predefoliation levels in heavily defoliated sites. Species that will increase include those that do not require a closed canopy and multistoried forest, and those that associate with herbaceous plants and woody brush. Standing dead trees will provide cavity-nests and den sites. Dead and down trees will provide den sites and habitat for a variety of animals.

Forest Condition

The condition of trees in the forest canopy will be degraded and mortality rates may increase—particularly in subdominant trees, even after only 1 year of heavy defoliation. Temporary declines in both new wood and hard mast will occur. Growth rates of many shrubs and herbaceous plants may increase.

After 2 years of heavy defoliation more than half of the subdominant oaks will probably die within 5 years, and heavy mortality is also possible among dominant oaks as well as in less-favored species. Hard and soft mast production, and wood production will be greatly reduced. Shoestring fungus and twolined chestnut borer will become more abundant. If heavy defoliation continues for 3 years,



The two-lined chestnut borer may kill trees weakened by defoliation.

Table 4-4. Changes in ecosystem components after a heavy gypsy moth outbreak

Ecosystem component[1]	Confidence	Heavy defoliation (> 60 percent) for. . . 1 year Short Term	1 year Long Term	2 years Short Term	2 years Long Term	3 years Short Term	3 years Long Term
Trees							
Condition R	High	–[2]	0	- -	0	- -	0
Mortality R	Intermediate	+	+	++	+	++	0
Diversity D	Intermediate	0	+	+	+	+	+
Pathogens A	High	+	+	+	+	++	++
Diameter growth R	High	–	0	- -	+	- -	+
Volume changes R	High	–	0	- -	+	- -	+
Shrubs A	High	+	+	+	+	+	++
Herbaceous cover A	Intermediate	+	+	+	+	+	++
Hard mast A	High	–	0	- -	?	- -	–
Soft mast A	Low	0	+	0	++	0	++
Fire hazard R	Low	0	+	0	++	+	++
Gypsy moth natural enemies A	High	+	0	++	0	++	0
Mammals D	Intermediate	0	0	0	+	0	+
Bats A	Low	0	0	0	0	0	+
Black bear A	Intermediate	0	0	0	0	0	0
White-tailed deer A	Intermediate	0	+	0	+	0	++
Gray squirrel A	High	–	–	–	–	–	- -
Deer mouse A	Intermediate	–	0	–	–	–	–
Birds D	High	0	+	0	+	0	+
Wild turkeys A	Intermediate	0	0	0	0	0	0
Ruffed grouse A	Intermediate	0	+	0	+	0	++
Neotropicals A	Intermediate	0	0	–	0	–	0
Reptiles and amphibians D	Low	–	+	–	+	- -	+
Timber rattlesnake A	Intermediate	–	0	–	0	–	0
Amphibians A	Intermediate	–	+	–	+	- -	+
Fish D	Low	0	0	0	0	0	0
Stream-using salmonids A	Low	–	–	–	–	–	–
Other game fish A	Low	0	0	0	0	0	0
Invertebrates D	Intermediate	0	+	0	+	0	+
Native lepidopterans D	Intermediate	–	0	–	0	–	0
Spring lepidopterans A	Intermediate	–	0	–	0	0	–
Summer lepidopterans A	Low	–	0	–	0	0	–
Litter invertebrates A	Low	+	0	+	0	?	0
Insect parasites and predators A	Intermediate	–	+	–	+	–	+
Spiders A	Intermediate	+	0	+	0	+	0
Pollinators A	Intermediate	0	+	0	+	0	+
Aquatic insects A	Low	+	+	+	+	+	+
Earthworms A	Intermediate	+	0	+	+	+	
Mollusks A	Low	–	?	–	?	–	?
Crustaceans A	Low	–	?	–	?	–	?
Detrital decay rate R	Low	+	+	+	+	+	+
Algal density A	Low	+	0	+	+	+	+

(continued)

Table 4-4. Continued

Ecosystem component[1]	Confidence	Heavy defoliation (> 60 percent) for. . . 1 year Short Term	1 year Long Term	2 years Short Term	2 years Long Term	3 years Short Term	3 years Long Term
Water							
Temperature A	Intermediate	+	+	+	+	+	+
Dissolved oxygen A	Low	–	0	–	–	–	–
Nutrients A	Low	+	+	+	+	+	+
Flow rate R	Intermediate	+	0	+	0	+	0
Yield A	Intermediate	+	0	+	0	+	0
Sediment load A	Low	+	0	+	0	+	0
Microclimate							
Soil-litter temperature A	High	+	0	+	0	+	0
Light below canopy A	High	+	+	+	+	+	+
Relative humidity below canopy A	High	–	0	–	0	–	0
Soil							
Decomposition rate R	Intermediate	+	0	+	0	+	0
Litter production A	Intermediate	0	0	0	0	0	0
Quantity organic matter A	Intermediate	+	0	+	0	+	0
Soil pH R	Low	0	0	0	0	0	0
Erosion rate R	Intermediate	0	0	0	0	0	0

[1] R = rate or appearance
D = diversity
A = abundance or quantity

[2] – = expected decrease
0 = no expected change
+ = expected increase
? = uncertainty

mortality will be high in oaks and will extend to less favored hosts as well. Wood production will be drastically reduced, and hard mast production will probably cease for at least 5 years. Shrubs and herbaceous plants, especially raspberry (*Rubus* L.), will increase dramatically.

After 1 year of heavy defoliation many subdominant trees will be removed in the long term, but few other effects will be noted. After 2 years of heavy defoliation stands will be one-storied, but surviving trees will recover and put on accelerated new growth and mast crops. Shrub cover will increase, as will red maple.

After three successive years of heavy defoliation, many or most of the overstory trees will be dead. Sites will revert to plants such as blueberry (*Vaccinium* L.), sweetfern (*Comptonia peregrina* [L.] Coult.), and raspberry, taking decades to regenerate to young forests. In areas where trees less favored by the gypsy moth remain, stands will be dominated by species such as red maple and yellow or black birches. In any event, without salvage, the fire hazard will increase. Resultant stands will be less susceptible to future gypsy moth outbreaks.

Water Quality

After heavy defoliation short-term impacts include elevated water temperatures, reduced dissolved oxygen levels, a decrease in acid neutralizing capacity in some streams, and elevated nitrate-nitrogen concentrations and water yields.

In the long term, these same water conditions may persist for years, although water yields should return to predefoliation levels.

Microclimate, and Soil Productivity and Fertility

After heavy defoliation, increased exposure to sunlight will cause seasonal elevations in the temperature of soil and leaf litter. Soil moisture content may increase temporarily. These factors will all lead to increased rates of soil decomposition, mineralization, and plant productivity in the area. These changes should be short-lived.

Effects Due to *Bacillus thuringiensis* var. *kurstaki* (*B.t.k.*)

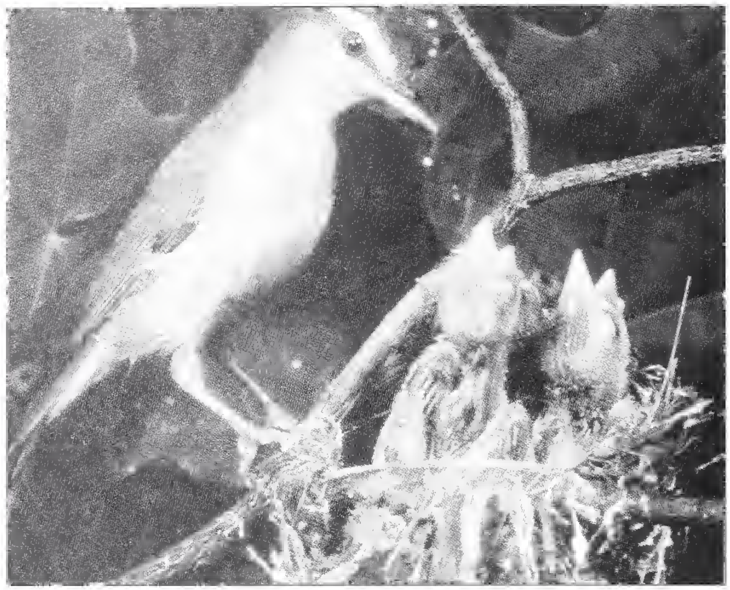
Hazard Identification

B.t.k. has a direct, adverse effect on the caterpillars of moths and butterflies, but susceptibility varies widely among species (Peacock and Schweitzer 1993). All of the field studies examined in the Ecological Risk Assessment showed some reductions among moths and butterflies, particularly in the year of treatment (Miller 1990a,b, Peacock and others 1993, Rodenhouse and Holmes 1992, Sample and others In press). Numbers of species may be reduced the year after treatment (Miller 1990b). Individual caterpillar species might be more susceptible to *B.t.k.* than gypsy moth is, as indicated by insecticidal activity more than a month after *B.t.k.* application (Johnson and others In press, Dulmage and Aizawa 1982, Pruett and others 1980).

The effects of *B.t.k.* on gypsy moth parasites (wasps and flies) appear to be indirect. Parasitism rates by the wasps *Cotesia* (=*Apanteles*) *melanoscelus* (Ratzeburg) and *Rogas lymantriae* Watanabe often increase in *B.t.k.*-treated areas, while those by the flies *Compsilura concinnata* Meigen and *Blepharipa pratensis* (Meigen) appear to decrease (e.g., Andreadis and others 1983, Ticehurst and others 1982, Wallner and others 1983).

B.t.k. does not affect sawfly caterpillars (Sample and others In press) or the overall abundance of "clinging" arthropods, including beetles (Coleoptera), sucking insects such as aphids, leafhoppers, or cicadas (Homoptera), and spiders (Arachnida) (Rodenhouse and Holmes 1992).

Any effects of *B.t.k.* applications on insectivorous birds due to a reduction in food availability are subtle. Mammals, including bats, that feed on moths and butterflies might also be affected indirectly by reductions in food abundance. Toxicity to fish is also low. While no toxicity data are available on reptiles and amphibians, *B.t.k.* is not believed to pose a hazard to these organisms.



The red-eyed vireo eats all life stages of the gypsy moth.

Most aquatic invertebrates are not affected by *B.t.k.*; however, no studies were found on aquatic lepidopteran caterpillars. *B.t.k.* has been shown to be toxic to some blackfly larvae of *Simulium vittatum* Zetterstedt, and *S. argus* Williston (Eidt 1985, Lacey and others 1978). Direct application of *B.t.k.*, at a rate equivalent to 300 BIU/ha (120 BIU/acre), to a section of forest stream had no measurable effects on the macroinvertebrate community composition or abundance, except for the stonefly *Leuctra tenuis* (Pictet) (Kreutzweiser and others 1993). A subsequent laboratory study has determined that *L. tenuis* was not affected by *B.t.k.* (Kreutzweiser 1995).

B.t.k. spores can persist in soil and protected places longer than can the crystal toxins and, under ideal conditions, can survive for several months or even years (West and others 1984). Natural epizootics attributable to *B.t.k.* have never been observed in nature (Reardon and others 1994). Ultraviolet light, as in natural sunlight, and temperature and moisture are important factors in the degradation of spores and crystals (Dulmage and Aizawa 1982, Ignoffo 1992).

Many studies indicate the insecticidal activity of sprayed *B.t.k.* lasts about a week in the environment, but a few reports suggest that it lasts longer. After aerial application, *B.t.k.* spores persisted in the forest

canopy up to 8 days on red oak (Sundarum and Sundarum 1992) and as long as 30 days on foliage of conifers (Smirnoff and others 1973). Under field conditions, two studies have estimated the time it takes for the insecticidal activity of *B.t.k.* to be reduced by half as ranging from 12 to 32 hours and from 24 to 32 hours (Reardon and others 1994). The *B.t.k.* crystal has been shown to lose its activity towards lepidopterans after 40 hours of exposure to simulated sunlight (Pozsgay and others 1987); however, insecticidal activity of *B.t.k.* has been observed for up to 42 days after spraying (Dulmage and Aizawa 1982). In another study *B.t.k.* was found to be toxic to first and second stage tiger swallowtail (*Papilio glaucus* Linnaeus) caterpillars for up to 30 days (Johnson and others In press). On the average applying *B.t.* at a rate of 90 BIU/ha (36 BIU/acre) gives insecticidal activity of at least an LD_{50} for 4 to 6 days (Reardon and others 1994). The cause of the prolonged insecticidal activity in some of these studies is not clear.

In aquatic environments 50 percent of the *B.t.k.* spores remained viable after 50 days in freshwater, but only 10 percent were viable after 30 days in seawater (Menon and DeMestral 1985).

Exposure Assessment

B.t.k. is aerially applied in spring to control gypsy moth caterpillars, when the target foliage averages at least 45 percent expansion (Reardon and others 1994). *B.t.k.* spores and crystals that penetrate the sparse upper canopy are distributed on the lower canopy and on ground vegetation, litter, and soil; and in any surface waters under the tree canopy. Spores and crystals also will fall off vegetation onto soil and litter, or into nearby surface water. Some will degrade naturally and some may be ingested by animals. Therefore, to characterize the risks posed by *B.t.k.* in gypsy moth treatment programs, residue levels were estimated for these parts of the environment: in upper and lower canopy leaves; at the soil or litter surface; and, in streams and ponds.

The Forest Service Cramer Barry Grim Model was used to simulate the dispersion of *B.t.k.* in a hardwood canopy typical of gypsy moth treatment areas using spray parameter values that represented environmental conditions and spray equipment commonly used in gypsy moth treatment projects (Teske and others 1993). Two application rates, 24 and 40 BIU/acre (59.3 and 98.8 BIU/ha), were examined. *B.t.k.* concentrations in aquatic ecosystems were determined for direct application to streams and ponds, which represents a reasonable worst-case situation because *B.t.k.* is not intentionally applied to water in gypsy moth treatment projects.

Most *B.t.k.* residues are deposited on the upper or lower canopy, and a smaller amount on the soil or litter surface. Organisms that could be exposed to *B.t.k.* include those that consume leaves, eat litter or the uppermost layer of soil, and eat dead or dying caterpillars that had consumed *B.t.k.* spores and crystals. It is not clear to what degree aquatic organisms might be exposed from a direct application of *B.t.k.* to water, since few studies have been conducted under natural conditions where the duration of exposure was known. *B.t.k.* spores and crystals have been found in the midgut of trichopteran species (caddisflies) in streams in areas treated with *B.t.k.* to control spruce budworm in Maine (Eco-Analysts 1981). Monitoring studies suggest that exposure to *B.t.k.* would not exceed about 2 weeks (Menon and DeMestral 1985).

Risk Characterization

Due to the relatively short insecticidal half-life of *B.t.k.* spores and crystals, the exposure and subsequent risk is limited to the time immediately after application. Because most toxicological studies do not estimate the concentration of *B.t.k.* in the diet of test organisms and how much the organism consumes, it is difficult to relate these studies to field conditions. Therefore, the risk of encountering a *B.t.k.* droplet was used to characterize risk. Caterpillars were considered to be at risk if they encountered one or more drops of *B.t.k.* This assumption overestimates risk in most cases, since diet and stage of development may moderate the insecticidal effect of *B.t.k.*

Nontarget Organisms

Some caterpillars of moths and butterflies are at risk from application of *B.t.k.* in gypsy moth treatment projects. Large caterpillars consume more vegetation than do small caterpillars and are more likely to encounter a *B.t.k.* drop (*table 4-5*). The risk of encountering a *B.t.k.* drop increases with application rate and height above the ground in the canopy. *B.t.k.* poses some risk only to spring-feeding caterpillars because of its relatively short insecticidal activity. Not all caterpillars are at risk, however, due to wide variation in response to *B.t.k.* between different species.

Table 4-5. Probability of a caterpillar encountering a *B.t.k.* drop, by caterpillar weight, location, and application rate of *B.t.k.*

Caterpillar weight (mg)	Upper canopy	Subcanopy	Ground surface
	percent		
	24 BIU/acre (59.3 BIU/ha) application rate		
0.75	12	2	2
2.5	90	40	32
5	99	82	76
10	100	98	97
50	100	100	100
100	100	100	100
	40 BIU/acre (98.8 BIU/ha) application rate		
0.75	42	8	6
2.5	99	76	69
5	100	96	94
10	100	100	100
50	100	100	100
100	100	100	100

Reduction in total numbers of lepidopterans is suggested by field studies (Miller 1990a, Peacock and others 1993, Sample and others In press). Some species appear to be particularly susceptible to *B.t.k.* as evidenced by their total, or nearly total, elimination from treatment areas (Peacock and others 1993). This result is not unexpected given the variable susceptibility to *B.t.k.* noted among several caterpillar species tested in the laboratory (Peacock and Schweitzer 1993).

Permanent changes in nontarget caterpillar populations do not appear likely in gypsy moth suppression projects, which normally consist of a single application of *B.t.k.* An exception might occur in certain habitat types that support small isolated populations of lepidopterans that are highly susceptible to *B.t.k.* If unaffected individuals of the same species are unlikely to, or physically cannot, move from untreated areas into the treated area, then one application of *B.t.k.* will have a greater effect on the ability of those populations to recover.

Data are sparse on the effects of multiple *B.t.k.* applications in one year and sequential yearly applications commonly used in gypsy moth eradication projects. In Oregon, Miller (1990b) observed reductions in both types and numbers of nontarget caterpillars after three applications of *B.t.k.* The reductions persisted for 1 year after treatment but not for 2 years.

A second application of *B.t.k.* did not increase mortality of five species of Lepidopterans over that caused by one application. The species tested were moderately resistant to *B.t.k.*, however, and had mortality rates below 50 percent after the first application (Carter 1995). Because of the variation in response to *B.t.k.* by lepidopterans, these results cannot be generalized to all species. The variable effects of *B.t.k.* on nontarget caterpillars noted in field studies, and the sparse data available on *B.t.k.* applications inject some uncertainty into the characterization of risk. Additional research on these topics would help to better quantify the risk.

Field studies suggest that the predominant effect of *B.t.k.* on gypsy moth parasites is indirect, through effects on its host species. At least two parasitic wasps of gypsy moth, *Cotesia* (=*Apanteles*) *melanoscelus* and *Rogas lymantriae*, have increased rates of parasitism in areas sprayed with *B.t.k.* (Wallner and others 1983, Webb and others 1989). Field studies on insects other than lepidopterans and their parasites and predators have found few other species or groups that are affected.

Vertebrates that feed on caterpillars in spring will have a reduced number of prey on which to feed for a short time. Reductions in caterpillar numbers from *B.t.k.* application forces a switch in diet for birds and mammals. In birds the number of nesting attempts per year may be reduced but not necessarily the

overall production of fledglings per breeding territory in the year of application or subsequent years (Rodenhouse and Holmes 1992). Bats that feed almost exclusively on lepidopterans might be indirectly affected through a reduction in prey, as suggested by a study in West Virginia (Sample and others 1993b). A 3-year study (1990-1992) conducted in West Virginia to determine the potential effects of *B.t.k.* on food of the endangered Virginia big-eared bat showed the greatest impact within 3 weeks of *B.t.k.* application. No moths on which the bats fed were significantly less abundant after *B.t.k.* application (Sample and others In press).

Most fish and aquatic invertebrates are unlikely to be affected. Fish that have alkaline digestive secretions, such as carp or koi, may be adversely affected by *B.t.k.* Additionally, a blackfly (Eidt 1985) and a stonefly (Kreutzweiser and others 1992) have shown effects from *B.t.k.* in laboratory studies, and a species of mayfly has shown decreased numbers after *B.t.k.* application in a field study (Oldland and others 1994).

Use of *B.t.k.* reduced the incidence of infection in gypsy moth populations by the nucleopolyhedrosis virus (Webb and others 1989, Woods and others 1988). *B.t.k.* treatments reduced the numbers of early stage caterpillars killed by NPV and the amount of viral inoculum released to the residual gypsy moth populations (Reardon and others 1994).

Forest Condition

B.t.k. reduces damage to trees caused by spring-feeding caterpillars. If trees do not have to produce a new set of leaves to replace those eaten by gypsy moth and other caterpillars, trees can grow more and produce more seeds. *B.t.k.* use, therefore, is likely to maintain the forest condition.

Water Quality

Water quality should not be directly affected by *B.t.k.*, as it is not likely to affect most aquatic organisms. Decreases in detritus decomposition rates demonstrated at high doses of *B.t.k.* in the laboratory are unlikely in the environment, given the purification processes in natural systems and the lower doses used in gypsy moth treatment projects (Kreutzweiser and others 1993).

By protecting tree foliage, *B.t.k.* reduces the likelihood of changes in water quality that might be associated with feeding of gypsy moth caterpillars.

Microclimate

B.t.k. minimizes the amount of defoliation caused by leaf-eating caterpillars. Therefore, change in microclimate due to defoliation is not expected after *B.t.k.* application.

Soil Productivity and Fertility

In one study areas treated with *B.t.k.* showed increased numbers of soil bacteria, actinomycetes, fungi, and nematodes, when compared with untreated areas (Petras and Casida 1985). In another study *B.t.k.* reduced populations of a predatory mite closely related to soil-dwelling species (Addison 1993). Nevertheless, changes in soil productivity and fertility are not likely, because *B.t.* occurs naturally in soils worldwide, applications of *B.t.* formulations do not increase levels of *B.t.* in soil, and *B.t.* spores and crystals persist for a relatively short time.

Effects Due to Diflubenzuron

Hazard Identification

Toxicity Data

The toxicity of diflubenzuron to terrestrial arthropods varies, but most laboratory studies show adverse effects at relatively high exposure levels. Toxic effects are often greater when diflubenzuron is ingested immediately before molting. Immature grasshoppers, beetle larvae, lepidopteran caterpillars, and fly larvae are most susceptible. Honeybees, parasitic wasps, and predatory insects exhibit greater tolerance to diflubenzuron exposure. Toxicity of diflubenzuron to aquatic organisms varies by taxa. Fish, snails, and bivalves are generally not affected at the concentrations used in gypsy moth projects. Diflubenzuron is highly toxic to aquatic insects, crustaceans, horseshoe crabs, and barnacles.

Toxicity data on 4-chloroaniline are limited. This breakdown product of diflubenzuron has been shown to be mutagenic and to have dose-related carcinogenic

activity in male rats (NCI 1979). Rapid metabolic breakdown and degradation in the environment, however, make sufficient exposure to cause these adverse effects unlikely.

No information was found on toxicity to reptiles or amphibians; and, due to diflubenzuron's mode of action, it is not likely that these organisms would be adversely affected.

Toxicity to green plants has not been observed. In a study of five species of fungi from different genera, growth of only one (*Pythium* sp.) was inhibited at 50 ppm diflubenzuron (Booth 1978).

Terrestrial Field Studies

Many field studies have examined the effects of diflubenzuron on nontarget organisms in terrestrial ecosystems. The Ecological Risk Assessment examined the results; however, their usefulness was limited because application rates exceeded those used in gypsy moth projects, as much as sixtyfold. Because some interpretation of these results would be necessary, they are not summarized here.

At application rates of 0.5-1.0 ounce of active ingredient per acre in gypsy moth projects, diflubenzuron was shown to reduce nontarget moth and butterfly populations in the year of treatment (Butler 1993, Butler and Kondo 1993, Martinat and others 1988, Sample and others 1993a). In some studies population levels were affected the year after treatment as well (Butler 1993, Sample and others 1993a). In one study, significant reductions in populations of macrolepidopterous larvae continued through the completion of the study, more than 27 months after treatment (Butler 1995). Numbers of macrolepidopterans were reduced significantly (Martinat and others 1988). The number of species was not affected (Sample and others 1993a).

When applied to early gypsy moth instars, diflubenzuron adversely affected the parasitic wasp *Cotesia* (=*Apanteles*) *melanoscelus* (Granett and others 1976, Madrid and Stewart 1981). Diflubenzuron apparently had no effect on the gypsy moth egg parasite *Ooencyrtus kuvanae* (Howard) at rates twice that commonly used in gypsy moth projects (Brown and Respicio 1981). Diflubenzuron was found to be toxic to the larvae of a parasitic fly (family Tachinidae), probably as an indirect result of death of the host due to diflubenzuron (Madrid and Stewart 1981).

Determining the effect of diflubenzuron on invertebrate predators and parasites of crop pests is more problematic, because the application rates of diflubenzuron used in the studies ranged from 2 to more than 60 times the application rates commonly used to control gypsy moths. Furthermore, some studies involved as many as nine applications. The numbers and types of ichneumonids and braconids, which include many parasitic wasps, were unaffected in forests sprayed with diflubenzuron for gypsy moth treatment (Sample and others 1993a).

Brood reduction, more eggs, and less comb production were evident in honeybee (*Apis mellifera* Linnaeus) hives when water containing diflubenzuron (60 ppm) was supplied to the hive for 40 days (Barker and Waller 1978). No effects were seen in bee colonies when hives were placed in areas treated with diflubenzuron at rates more than 10 times that used in gypsy moth projects (Buckner and others 1975). Other invertebrates are susceptible to diflubenzuron, especially immature stages of leaf-eating species, such as grasshoppers and other orthopterans (Butler 1993, Everts 1990, Jech and others 1993, Martinat and others 1993), some juice-feeding insects (Butler 1995), sawflies, some beetles, wood lice, and some homopterans (Butler 1993, Martinat and others 1988). Populations of other species in several different families of beetles, wasps, ants, and flies were not affected (Sample and others 1993a).

Spiders were adversely affected at diflubenzuron rates used in gypsy moth projects (Everts 1990, Martinat and others 1993, Perry and others 1993). Soil mites, however, appeared to have varying degrees of susceptibility, and some were not affected at all (Blumberg 1986, Perry and others 1993).

Studies of gypsy moth projects in the Appalachian Mountains of West Virginia evaluated the impacts of diflubenzuron on a forest ecosystem. Organisms sampled in these mostly unpublished studies included pollinating insects, canopy arthropods, soil microflora, soil arthropods, and salamanders (Reardon 1993). The overall effect on pollinators was relatively slight. Among 100 species of bees, 50 species of flower flies, and 5 species of bee flies (Diptera), beetles (Coleoptera), and yellowjackets and European hornets, numbers of flower flies, yellowjackets, and hornets decreased significantly on treated plots. The principal effect

on canopy arthropods was on foliage eating groups, with major reductions in lepidopterans. Evaluation of 134 species of macrolepidopterous larvae by foliage pruning and tree banding showed long-term reductions in some of these species. Cellular slime molds were unaffected the year of treatment in one study.

The effects on insectivorous birds including neotropical migrants will be indirect due to a reduction in food resources. Indirect effects, such as enlarged territories on treated plots versus untreated plots and reduced fat levels in birds collected on treated plots, have been correlated with significant reductions in populations of lepidopterans, which resulted from applications of diflubenzuron (Cooper and others 1990, Sample and others 1990, Whitmore and others 1993).

After aerial application of diflubenzuron in an Appalachian forest, populations of many species of moths consumed by the endangered Virginia big-eared bat were reduced, but not significantly (Sample and others 1990). The effects on lepidopterans in general could have indirect effects on bats that consume moths.

Preliminary analysis of a study in West Virginia (Reardon 1993) indicated that an aquatic salamander (*Desmognathus monticola* Dunn) apparently shifted its diet to include more ants and fewer winged hymenopterans after its habitat was treated with diflubenzuron (Pauley 1994).

Aquatic Field Studies

Diflubenzuron has no direct effect on freshwater plants (Eisler 1992).

Invertebrates in freshwater lakes, ponds, and marshes were adversely affected by exposure to diflubenzuron, especially crustaceans, such as zooplankton and amphipods (scuds), and insects such as dipterans (true flies), chironomids (midges), mayflies, odonates (dragonflies and damselflies), and corixids (water boatmen) (Ali and Mulla 1978a,b, Apperson and others 1978, Eisler 1992, Fischer and Hall 1992, Hansen and Garton 1982, Sundaram and others 1991).

At rates as low as 28-56 grams of active ingredient per hectare (0.4-0.8 oz a.i./acre), diflubenzuron effectively reduced numbers of many pestiferous dipterans and suppressed nontarget populations of cladocerans, copepods, mayfly

Mayflies may be adversely affected if enough diflubenzuron enters streams or ponds.

nymphs, corixids, and springtails in river and stream habitats (Eisler 1992). Stoneflies and mayflies apparently were most affected by diflubenzuron (Hansen and Garton 1982, Harrahy and others 1994, Mayer and Ellersieck 1986).

Vertebrates in freshwater habitats tolerate direct exposures to diflubenzuron (Eisler 1992), although fish may respond by switching to other prey (Apperson and others 1978, Colwell and Schaefer 1980).

Numerous studies have substantiated effects of diflubenzuron on marine crustaceans (Eisler 1992, Fischer and Hall 1992). A diflubenzuron application of 45 g a.i./ha (0.6 oz a.i./acre) to a tidal pool caused 46.5 percent mortality in juvenile blue crabs (Hester and others 1986). Saltwater fish are resistant to diflubenzuron (Fischer and Hall 1992).

Exposure Assessment

Fate and Transport in Undeveloped Areas

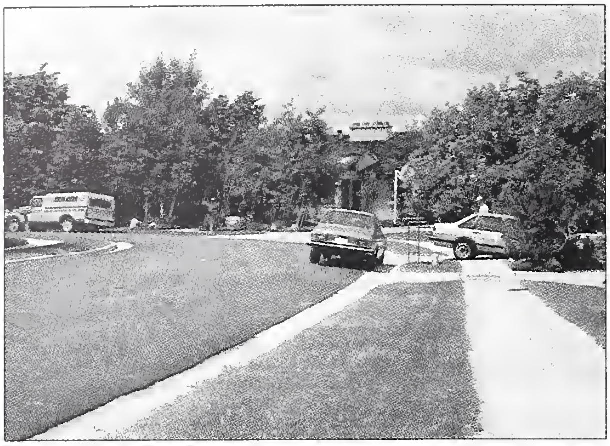
Virtually all of the studies on the fate and transport of diflubenzuron have been conducted in undeveloped areas (natural forest). Diflubenzuron sprayed over undeveloped land settles on the canopy or falls directly to the forest floor. Immediately after application, diflubenzuron begins to be transported, degraded, or ingested through various mechanisms and pathways. Between 20 and 80 percent of diflubenzuron residue on leaf surfaces is washed off or abraded during the first 2 to 3 weeks after spraying (Martinat and others 1987, Wimmer and others

1993). The abraded residues contribute to those already present in the leaf litter from direct spray, and to those that remain from any diflubenzuron treatments the previous year. Some of these residues degrade during the remainder of the spring and summer through the action of microorganisms in the litter and soil (Nigg and others 1986, Nimmo and others 1984, Verloop and Ferrell 1977, Wimmer 1994).

Diflubenzuron slowly diminishes throughout the summer, and by autumn 50 to 95 percent of the diflubenzuron residue has been removed from leaves in the canopy (Wimmer and others 1993). The remaining 5 to 50 percent falls to the forest floor with the leaves in autumn. Diflubenzuron remains in the litter throughout the winter until degradation (microbial action) accelerates with increasing temperatures the following summer (Bull and Ivie 1978). Residues remaining in litter at the end of this second summer are diluted by uncontaminated foliage at leaf fall, assuming the area was not resprayed.

A relatively small amount of diflubenzuron enters streams, rivers, or estuaries either by direct spray filtering through the canopy or by runoff after adhering to organic debris. Diflubenzuron falling directly into streams or ponds is either diluted or rapidly adheres to organic sediments where its fate parallels diflubenzuron in the soil (Booth and Ferrell 1977, Carringer and others 1975, Chapman and others 1985, Schaefer and Dupras 1976, Sundaram and others 1991). In water, diflubenzuron is more stable in more acidic conditions or lower temperatures (Ivie and others 1980, Schaefer and Dupras 1976). An additional pulse of diflubenzuron enters streams with fallen leaves (Harrahy and others 1993). As in the terrestrial environment, these residues persist on the submerged leaf material throughout the winter and degrade as temperatures increase the following spring and summer (Harrahy and others 1993, Swift and others 1988).

The persistence of diflubenzuron in the environment might vary somewhat depending on average summer and winter temperatures. Residues have been found to persist through winter in Appalachian hardwood forests in West Virginia and in cotton fields in Texas. Overwintering residues might be expected in most States, except perhaps in the extreme Southwest where the growing season is long and soil temperatures presumably are high enough to allow microbial activity to continue at moderately high rates in fall and winter. Conversely, residues might persist through a second winter in colder regions with short growing seasons.



Sidewalks and roads may affect the movement and fate of diflubenzuron in the environment.

Fate and Transport in Developed Areas

The same factors responsible for degradation of diflubenzuron in undeveloped areas operate in developed areas. The main difference between these two environments that could affect the fate and transport of diflubenzuron is the area covered by impervious (waterproof) surfaces, such as roofs, roads, sidewalks, and parking lots, in developed areas. These surfaces substantially change the natural flow of water. Storm water and the debris it collects are deposited directly into local streams via runoff from streets, gutters, and storm sewers, rather than percolating through the soil with minimal overland flow.

No studies have been found on the effect of impervious surfaces (asphalt and concrete) on the fate and transport of diflubenzuron. The physical properties of diflubenzuron and its behavior in the field suggest that it will readily bind to asphalt, which is high in organic content, but not to concrete, which is a matrix of sand, gravel, clay, and limestone.

Some diflubenzuron is assumed to wash from asphalt surfaces during a storm, as happens in the tree canopy, adding to that washing from concrete and resulting in greater inputs into streams in developed

forests. The fate of diflubenzuron in many streams in developed areas will likely be similar to that in streams in natural areas: it will bind quickly to organic debris and sediments and decline throughout the summer from microbial activity. Leaf debris carried into waterways in late fall and winter may harbor residues, which degrade when temperatures warm the following spring and summer. In residential areas that have leaf collection programs in fall, residues remaining on the leaves will be concentrated in landfills or compost heaps. Diflubenzuron is expected to degrade rapidly in compost heaps, because they typically have high microbial activity and temperatures, even in fall and winter (Fogarty and Tuovinen 1991).

Exposure Modeling

Three models were used to estimate diflubenzuron residues in various parts of the environment: (1) Forest Service Cramer Barry Grim Model for aerial dispersion and deposition in a treatment area (Teske and others 1993); (2) Pesticide Root Zone Model (PRZM) for estimating concentrations in runoff water (Carsel and others 1984); and (3) a surface water model for estimating the concentration in a typical stream and pond receiving storm runoff.

Using the FSCBG model, residues were estimated for one diflubenzuron application and a second application at the same rate 1 week later. Four rates of application were examined: 0.25, 0.33, 0.5, and 1.0 ounces active ingredient per acre (17.5, 23.3, 35, and 70 g a.i./ha). The model parameters chosen represent the environmental conditions and equipment common to gypsy moth projects. Diflubenzuron residues on leaves decrease over time, so residues were determined immediately after application, and at the end of the growing season. Diflubenzuron persistence on leaves was assumed to be similar to that observed in West Virginia (Wimmer and others 1993).

Diflubenzuron concentrations were also estimated for soil, leaf litter, and for water directly sprayed. The PRZM was used to estimate the diflubenzuron concentration in runoff from a sprayed watershed. Model parameters were selected to maximize the concentrations of diflubenzuron that could reasonably be expected in runoff, to provide a worst-case scenario for aquatic organisms (Gray and Beauman 1994).

Although diflubenzuron is not intentionally applied directly to water in gypsy moth projects, small streams under a tree canopy may inadvertently receive diflubenzuron. In the risk assessment, the concentration of diflubenzuron in a small stream sprayed directly was considered to be a worst case situation. Diflubenzuron concentrations in small streams and shallow ponds receiving runoff from the sprayed area were determined for developed areas and undeveloped areas using a surface water runoff model. Diflubenzuron concentrations in aquatic sediments were assumed to be 2 percent of the concentration in water, based on a monitoring study (Kingsbury and others 1987). Concentrations of 4-chloroaniline in water were assumed to be 10 percent of the diflubenzuron concentration (Schaefer and others 1980).

Most diflubenzuron spray falls on the tree canopy.

Results of the modeling show that most diflubenzuron residue falls on the upper and lower tree canopy, with smaller amounts reaching the soil or litter surface. Diflubenzuron concentrations are low in the directly sprayed stream, and even lower in water receiving runoff. Water in developed areas has higher diflubenzuron concentrations than that in

undeveloped areas. As expected, the higher the application rate of diflubenzuron, the higher the residues on all surfaces. Applying diflubenzuron twice at a low rate results in residue levels similar to those from one application at a higher rate. The modeling results are comparable, although generally higher, to diflubenzuron residues observed in Appalachian hardwood forests of West Virginia (Wimmer and others 1993).

Upper canopy leaves in spring have the highest diflubenzuron concentration of any vegetation. Because diflubenzuron persists on leaves and in leaf litter, diflubenzuron concentrations will remain on leaves throughout the growing season or, in the case of litter, into the next growing season. The modeling results tend to overestimate diflubenzuron concentrations on canopy leaves and slightly underestimate it in the litter, compared with field studies (Martinat and others 1987, Wimmer 1994).

Diflubenzuron concentrations were greater in streams and ponds in developed areas than in undeveloped areas. Concentrations in streams increase rapidly after runoff, but also decline rapidly within 24 hours of runoff.

Organisms that consume leaves, leaf litter, or soil in treated areas could ingest diflubenzuron residues. In developed areas, these include organisms that ingest turf grasses. Sucking insects, wood-boring organisms, and pollen- and nectar-feeding insects are not likely to be exposed. Soil arthropods that consume litter and fallen leaves could be exposed twice: when diflubenzuron is applied, and at leaf fall in autumn. In aquatic habitats bottom-dwelling organisms may be exposed to diflubenzuron in sediments. Fish and other organisms may be exposed to diflubenzuron in water. Leaf shredders and chewers are exposed to diflubenzuron when leaves fall from the trees and accumulate in streams.

Risk Characterization

The risk of diflubenzuron exposure causing changes in nontarget species was assessed quantitatively. Screening indices were developed for a variety of organisms including all of those potentially exposed by ingesting diflubenzuron. A screening index takes the amount of diflubenzuron on a given substrate (for example, leaves), based on the exposure modeling results and compares it with a known toxicological benchmark, such as an LD_{50}, adjusted to include a safety factor. On the basis of a Monte Carlo simulation of the screening index, organisms with a greater than 1 percent risk of exceeding the screening index were considered potentially at risk from diflubenzuron.

The next step was to determine the percentage of the population at risk from diflubenzuron. This was estimated using the relationship between diflubenzuron concentrations and population response. Since the same sources of variation exist for this calculation as for the screening index, a Monte Carlo simulation was run for each group at or exceeding the screening index (Spain 1982). The results, shown in *tables 4-6* and *4-7*, are the mean population response and the risk of at least 50, at least 75, or at least 90 percent reductions in the populations of a given group of organisms.

Reductions of lepidopteran populations based on LC_{50} values probably substantially underestimated risk because these toxicological studies addressed only mortality of test organisms over a relatively short period. The EC_{50} data are probably more indicative of natural mortalities because these data are based on failure to molt, which would have resulted in mortality had the toxicological test been longer.

The risk of changes in the other endpoints (forest condition, water quality, microclimate, and soil productivity and fertility) were estimated qualitatively.

Nontarget Organisms

Moths and butterflies, grasshoppers, parasitic wasps, benthic crustaceans, aquatic insects, and immature planktonic crustaceans are directly at risk from the lowest application rate of diflubenzuron used in gypsy moth programs. Increasing the application rate causes a larger reduction of these populations (*tables 4-6* and *4-7*). At higher application rates there is a higher risk of affecting at least 50 percent of these populations. Higher application rates also increase the types of species groups affected; more aquatic organisms are at risk at the highest application rate (1.0 oz a.i./acre) than at the lowest (0.25 oz a.i./acre).

Table 4-6. Percentage of nontarget populations affected by diflubenzuron applications at 1.0 and 0.5 ounce active ingredient per acre, as determined by modeling

Type of organism	Application rate: 1.0 oz a.i./acre (70.1g/ha) Mean population reduction	Risk of population reduction as large as 50%	75%	90%	Application rate: 0.5 oz a.i./acre (35.1 g/ha) Mean population reduction	Risk of population reduction as large as 50%	75%	90%
	percent							
Terrestrial organisms								
Spring lepidopterans upper canopy LC_{50}	65	75	41	7	50	49	19	2
Spring lepidopterans lower canopy LC_{50}	57	62	27	4	41	37	11	<1
Fall lepidopterans upper canopy LC_{50}	44	42	15	2	29	21	5	<1
Fall lepidopterans lower canopy LC_{50}	42	38	12	1	27	17	4	<1
Spring lepidopterans upper canopy EC_{50}	95	99	95	69	91	97	86	47
Spring lepidopterans lower canopy EC_{50}	93	98	91	58	85	93	77	37
Fall lepidopterans upper canopy EC_{50}	87	93	78	42	76	83	61	23
Fall lepidopterans lower canopy EC_{50}	86	94	78	37	75	82	58	19
Spring orthopterans (grasshoppers) upper canopy	97	100	100	88	91	100	94	52
Spring orthopterans lower canopy	95	100	98	72	85	98	84	31
Fall orthopterans upper canopy	85	96	83	42	72	81	56	12
Fall orthopterans lower canopy	84	93	85	31	69	81	49	8
Ants (litter-eaters)	>99	99	97	84	93	94	84	56
Predatory insects	17	9	2	0	<1	1	0	0
Parasitic wasps of gypsy moth upper or lower canopy	>99	100	100	100	>99	100	100	100
Aquatic organisms								
Direct spray								
Benthic midges	20	10	6	1	5	2	1	0
Benthic crustaceans	98	100	100	60	92	100	100	60
Benthic insects (mayflies, caddisflies)	60	90	2	0	58	85	1	0
Planktonic insects	>99	100	100	100	98	100	100	100
Planktonic crustaceans—nymphs	98	100	100	62	81	98	74	22
Planktonic crustaceans—adults	11	2	1	0	5	1	<1	<1
Residential forest pond								
Benthic crustaceans	89	100	99	38	89	100	99	36
Planktonic insects	98	100	100	100	98	100	100	100
Planktonic crustaceans—nymphs	94	95	62	15	76	94	60	13
Residential forest stream								
Benthic midges	19	9	2	1	17	10	1	0
Bentic crustaceans	97	100	100	97	97	100	100	95
Benthic insects (mayflies, caddisflies)	58	86	1	0	57	82	1	0
Planktonic insects	>99	100	100	100	>99	100	100	100
Planktonic crustaceans—nymphs	91	100	97	49	90	100	96	46
Forest pond								
Planktonic insects	89	91	79	64				
Forest stream								
Benthic crustaceans	90	100	100	40	61	88	27	2
Planktonic insects	98	100	100	100	97	100	100	99
Planktonic crustaceans—nymphs	76	95	61	15	44	34	10	0

Table 4-7. Percentage of nontarget populations affected by diflubenzuron applications at 0.33 and 0.25 ounce active ingredient per acre, as determined by modeling

Type of organism	Application rate: 0.33 oz a.i./acre (23.1g/ha)				Application rate: 0.25 oz a.i./acre (17.5 g/ha)			
	Mean population reduction	Risk of population reduction as large as 50%	75%	90%	Mean population reduction	Risk of population reduction as large as 50%	75%	90%
Terrestrial organisms								
Spring lepidopterans upper canopy LC_{50}	39	34	9	<1	34	25	6	<1
Spring lepidopterans lower canopy LC_{50}	32	22	5	<1	27	17	3	<1
Fall lepidopterans upper canopy LC_{50}	21	12	2	<1	17	8	1	<1
Fall lepidopterans lower canopy LC_{50}	19	9	2	<1	16	6	1	<1
Spring lepidopterans upper canopy EC_{50}	84	92	75	34	80	89	68	26
Spring lepidopterans lower canopy EC_{50}	78	87	64	27	74	82	56	19
Fall lepidopterans upper canopy EC_{50}	68	73	46	14	63	67	40	10
Fall lepidopterans lower canopy EC_{50}	66	71	41	11	61	64	37	8
Spring orthopterans (grasshoppers) upper canopy	83	97	79	27	78	92	67	16
Spring orthopterans lower canopy	75	89	60	13	68	82	47	7
Fall orthopterans upper canopy	59	65	33	5	51	53	23	2
Fall orthopterans lower canopy	56	59	25	2	48	48	16	1
Ants (litter-eaters)	83	85	68	36	76	77	57	25
Predatory insects	<1	0	0	0	<1	0	0	0
Parasitic wasps of gypsy moth upper or lower canopy	>99	100	100	100	>99	100	100	100
Aquatic organisms								
Direct spray								
Benthic midges	<1	1	0	0	<1	1	0	0
Benthic crustaceans	86	99	92	28	79	96	71	16
Benthic insects (mayflies, caddisflies)	56	86	1	0	55	85	1	0
Planktonic insects	96	100	100	94	94	100	100	71
Planktonic crustaceans—nymphs	71	83	48	11	61	65	34	7
Residential forest pond								
Benthic crustaceans	88	100	99	35	59	100	99	36
Planktonic insects	98	100	100	100	98	100	100	100
Planktonic crustaceans—nymphs	76	94	59	12	76	94	59	14
Residential forest stream								
Benthic crustaceans	97	100	100	95	97	100	100	95
Benthic insects (mayflies, caddisflies)	56	80	0	0	56	81	1	0
Planktonic insects	>99	100	100	100	>99	100	100	100
Planktonic crustaceans—nymphs	90	100	95	44	90	100	95	45
Forest stream								
Benthic crustaceans	61	79	20	0	60	77	20	0
Planktonic insects	84	100	99	8	84	100	99	5
Planktonic crustaceans—nymphs	40	29	8	0	40	28	8	0

Terrestrial Organisms

Although there were differences in diflubenzuron concentrations in the upper and lower canopy, species were either at risk in both habitats, or not at risk in either. Differences in diflubenzuron concentrations between spring and fall did not change the risk for groups analyzed for both seasons—moths, butterflies, and grasshoppers. The mean population reduction was greater, however, for species feeding in the upper canopy than in the lower canopy and for species feeding in spring than in fall. Results from field studies on the effects of diflubenzuron on nontarget terrestrial organisms corroborate the results of the risk modeling.

Parasitic wasps of gypsy moths are at risk as found in the field studies and in the risk modeling; however, the mechanism by which they suffer is unclear. Field studies suggest that populations of parasites of other species of insects will be mostly unaffected by diflubenzuron treatments. Modeling results and field studies suggest that predators such as lacewings, ladybird beetles, big-eyed bugs, and others are largely unaffected by diflubenzuron treatments.

Ground spiders were studied in the field, but risk to them was not modeled because toxicological data were lacking. Ground spiders could be indirectly affected through prey reduction or directly affected by diflubenzuron applications. The effects noted in field studies were not universal among the groups analyzed: some taxa were affected more than others, and overall species diversity remained unchanged (Everts 1990, Martinat and others 1993, Perry and others 1993).

Vertebrates, beetles, and earthworms are not directly at risk from diflubenzuron.

Although birds were not identified as being at risk from diflubenzuron in the modeling results, field studies suggest that subtle effects might occur for some insectivorous species. Thus far studies have not found reductions in overall reproductive success for breeding birds in treated plots. Indications are clear, however, that birds may show effects such as a switch in diet, reduced fat loads, and enlarged foraging territories from a reduction in food resources. Similar indirect effects may occur for bats that feed primarily on lepidopterans.

Aquatic Organisms

Although the estimated environmental concentrations of diflubenzuron differ for aquatic habitats in undeveloped and developed areas, there were few differences in groups of aquatic organisms at risk from diflubenzuron applications between the two ecosystems. Benthic insects were at risk in all but the natural forest pond (the habitat with the lowest diflubenzuron concentration). Planktonic crustaceans were at lower risk in undeveloped areas. The risk to some types of benthic insects may have been overestimated because the toxicological data used were LC_{50} values from mayflies and caddisflies. Field studies tend to corroborate the modeling results. Mollusks were not at risk according to the modeling results. Although not explicitly modeled, if diflubenzuron entered small brackish streams at concentrations similar to those estimated in fresh water, immature shrimp and crabs likely would be at some risk.

Modeling results indicate that at the highest application rate (1.0 oz a.i./acre), the no-observed-effect concentration of diflubenzuron for fish could be exceeded in the residential forest stream and in any stream that is directly sprayed with diflubenzuron. Fish are not at risk of mortality from exposure to diflubenzuron as used in gypsy moth projects. Field studies suggest, however, that fish could suffer indirect effects through prey reduction but will compensate by eating alternate prey.

Multiple Applications and Recolonization Rates

Two applications of diflubenzuron 1 to 2 weeks apart would present the same risk to most organisms as would one application at twice the application rate. This comparison is based on the similarity between the estimated diflubenzuron residues from two lower applications with rates which approximately equal that from one higher application rate. Consecutive annual applications of diflubenzuron would result in higher risk to litter invertebrates than would a single application, because some diflubenzuron residues overwinter and would persist into the following spring when the next application would be applied.

Determining species at risk of being eliminated within the spray area is more difficult. For many invertebrates there are no data on migration rates into

new areas. Also, natural population levels and how they vary from year to year are not known for most species. Nevertheless, some generalizations can be made:

- Susceptible organisms that produce multiple generations per year and are exposed to persistent diflubenzuron (for example, on leaves, or leaf litter) will be more likely to be affected severely than similar organisms that produce a single generation per year.
- Organisms with high dispersal rates will be able to reinvade treated areas.
- Organisms whose populations were severely reduced by diflubenzuron and have low dispersal rates will be affected for the longest time.
- Low dispersal capabilities of organisms, treatment of a large area, and frequent retreatment of an area will hinder rapid recolonization.

Forest Condition

Diflubenzuron is not poisonous to plants and has no direct effect on them. Diflubenzuron may indirectly help to maintain existing forest conditions by reducing gypsy moth populations and thereby protecting tree foliage.

Water Quality

Diflubenzuron reduces numbers of stream invertebrates that process detritus; however, field studies have not shown any decline in detrital decomposition rates (Swift and others 1988). Populations of many invertebrates that feed on algae are reduced by diflubenzuron. An increase in algae could occur after the loss of algal herbivores, however, this has not been observed in field studies.

Microclimate

Diflubenzuron indirectly helps to maintain the existing microclimate by decreasing the amount of defoliation by the gypsy moth and other defoliators.

Soil Productivity and Fertility

Earthworms are not at risk from diflubenzuron. Other litter invertebrates, particularly mites and ground-dwelling spiders, appear to be at risk based on field studies (Perry and others 1993). At least one field study suggests, however, that decomposition rates are not affected by diflubenzuron (Rockwood 1995). Further toxicological testing of litter invertebrates and field studies measuring decomposition, organic matter content, bacterial and fungal populations, and litter invertebrate populations would help shed light on any effects that diflubenzuron might have on soil productivity and fertility.

Effects Due to Gypchek

Hazard Identification

The nucleopolyhedrosis virus is highly pathogenic to early stage caterpillars of the gypsy moth (Doane 1967, Magnoler 1970), but has been shown to be noninfectious to other species of insects including the closely related Douglas-fir tussock moth (*Orgyia pseudotsugata* [McDunnough]) (Anonymous 1976, Barber and others 1993, Maramorosch and others 1976). Safety tests have shown that the virus product, Gypchek, is not toxic to mammals (including humans), birds, fish, and terrestrial and aquatic invertebrates. Positive correlations were significant between incidence of disease caused by the virus and incidence of the gypsy moth parasites *Cotesia* (=*Apanteles*) *melanoscelus* and *Parasetigena silvestris* (Robineau-Desvoidy) (Reardon and Podgwaite 1976). Populations of *Cotesia* (=*Apanteles*) *melanoscelus* were reduced compared with control plots, however, after treatment with 1.25×10^{12} occlusion bodies per hectare (5×10^{11} OB/acre) of the virus product Gypchek (Webb and others 1989). This parasitic wasp apparently avoids gypsy moth caterpillars infected with the nucleopolyhedrosis virus (Versoi and Yendol 1982).

The persistence of nucleopolyhedrosis virus has been tested on leaf, bark, leaf litter, and soil samples taken from areas where gypsy moth outbreaks and viral epizootics were observed, and from areas treated with Gypchek. Naturally occurring virus was found to have measurable activity for about 1 year compared with just 3-15 days for Gypchek (Podgwaite and others 1979). The virus has been found in soil under leaf litter, on the shed skins of

caterpillars, and on tree bark (Weseloh and Andreadis 1986, Woods and others 1989). Egg masses deposited on contaminated bark became infected (Murray and Elkinton 1990). The site of oviposition is more important than infested parents (transovum transmission) in transmission of the virus (Murray and Elkinton 1989). These results demonstrate the importance of oviposition site in the transmission of the virus in high-density populations or after epizootics and suggest that transmission by adults is not common.

Nucleopolyhedrosis virus is probably transported in the environment in many ways—via wind, rain, parasites, predacious insects, and by infected caterpillars (Lautenschlager and others 1980). Mammals and birds pass viable virus through their gut without becoming infected (Lautenschlager and Podgwaite 1979, Lautenschlager and others 1977).

Exposure Assessment

The virus is specific to gypsy moth caterpillars and has not been shown to pose a hazard to nontarget organisms, either terrestrial or aquatic. Therefore, an extensive quantitative exposure assessment was not performed. Gypchek residues were estimated to be 12,355 OB/cm^2 based upon an application rate of 5×10^{11} OB/acre over a flat surface with no vegetative cover. This calculation overestimates the amount of Gypchek that would be expected on vegetation in a forested area.

Risk Characterization

The risk characterization for Gypchek is qualitative. Quantitative calculations of risk were not performed, because the virus is specific for the gypsy moth and effects on nontarget organisms have not been demonstrated. The use of Gypchek will minimize changes in forest condition and water quality that might otherwise occur from the presence and feeding of the gypsy moth, and is not likely to cause changes in forest conditions or water quality. The use of Gypchek is not likely to cause changes in microclimate, or soil productivity and fertility.

Effects Due to DDVP in Mass Trapping

Mass trapping uses traps baited with the synthetic pheromone disparlure, to capture male gypsy moths before they have a chance to locate and mate with females. Large-capacity (milk carton) traps that might be used for this treatment contain an insecticide, called dichlorvos or DDVP (2,2,dichloroethenyl dimethyl ester phosphoric acid), to kill the male moths that are attracted. A plastic strip is impregnated with this organophosphate insecticide (Vaportape II) and slowly releases it over time. The smaller delta trap usually used in mass trapping does not contain DDVP. Both the milk carton and delta traps contain the manufactured gypsy moth sex attractant, disparlure. The ecological effects of disparlure are presented in the next section on Effects Due to Disparlure in Mating Disruption.

Hazard Identification

Vaportape II is distributed in packages of 50 strips. A strip consists of a 1- by 4-inch, multilayered polyvinyl chloride (PVC) tape containing 590 mg of DDVP.

DDVP is toxic to mammals, birds, aquatic and terrestrial invertebrates, and fish. No terrestrial or aquatic field studies are available on the effects of the DDVP strips on nontarget organisms. Observations of workers collecting traps, however, report occasional finds of small mammals such as mice or squirrels nesting in the traps without apparent ill effects. Nontarget insects that inadvertently enter the traps are often killed.

Exposure Assessment

A comprehensive analysis of the fate and transport of DDVP in the environment was not conducted because the DDVP strip is deployed and enclosed in traps. Contact of the DDVP strip with vegetation, soil, or water could occur by accident only if a trap is broken into or destroyed, and the

strip falls to the ground. While black bears reportedly damage traps, few nontarget organisms are likely to come into contact with the strip.

Exposure to DDVP is limited to those organisms that enter a milk carton trap or encounter a DDVP strip from a broken trap on the forest floor. Most insects will die from inhaling DDVP vapors in the trap. Ingestion is the primary exposure route for vertebrates, however, the strip is not palatable and probably would not be eaten by most animals.

When first removed from its protective pouch, a strip contains 590 mg (0.02 oz) of DDVP. The release rate of the strip is about 4 percent per day, based upon a 12-week field study. At this rate about half of the DDVP will dissipate after 17 days, and nearly all of it will dissipate after 100 days.

Risk Characterization

Plastic strips impregnated with DDVP were used in about 10 percent of the gypsy moth pheromone traps purchased by the U.S. Department of Agriculture in 1994, which represents a relatively minor use in gypsy moth programs. The manner in which the traps are deployed and the formulation of the strip limits possible exposure to the various components of the environment. Therefore, a quantitative assessment of risk was not conducted.

Invertebrates that inadvertently enter pheromone traps with DDVP are likely to die. Invertebrates that come into contact with a DDVP strip that has accidentally fallen on the ground, vegetation, or in water might also be at some risk. The risk of mortality, however, decreases over time as DDVP dissipates from the strip.

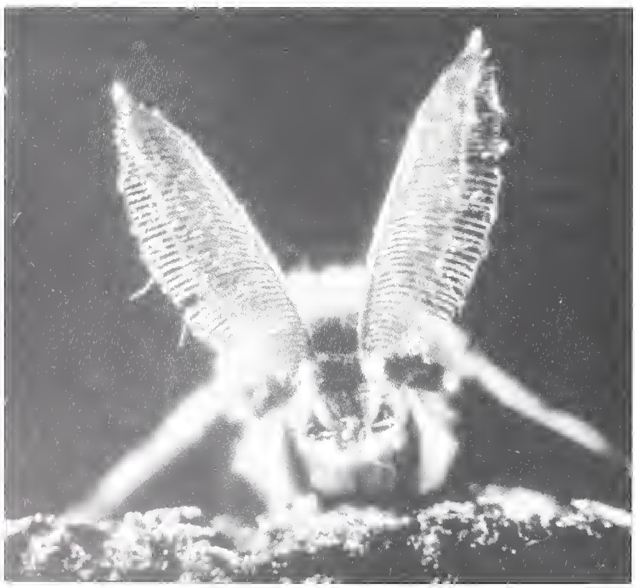
Large vertebrates, such as bears, are not likely to be at risk from DDVP strips. Each strip contains 590 mg of DDVP initially making the dose for a small bear (30 kg) about 20 mg/kg/day. This dose is lower than the LD_1 reported for DDVP (Wagner and Johnson 1970), although it is higher than the no-observable-effect level for acetyl cholinesterase inhibition and systemic effects in dogs (0.08 mg/kg/day) (U.S. EPA 1989a). The dose would decline by about 50 percent in 17 days and would be zero 100 days after trap deployment. The potential effects to individual nontarget organisms declines over time, as does risk.

DDVP strips as used in large-capacity gypsy moth pheromone traps are not likely to directly cause or create changes in nontarget species or their populations, forest condition, water quality, microclimate, or soil productivity and fertility.

Effects Due to Disparlure in Mating Disruption

Disparlure is used as a mating disruptant and—in much smaller amounts—as a lure for mass trapping, monitoring, and delimiting gypsy moth populations. The summary of risks associated with disparlure presented here should apply to these others uses as well. Mating disruption involves the aerial application of disparlure, formulated into tiny plastic dispensers that release the pheromone over time. The purpose of the application is to saturate an area with so many point sources of pheromone that the male moth is unable to locate and mate with females.

Disparlure has two enantiomers: (+) and (–). The term enantiomer refers to molecules that are structurally identical except for differences in the three-dimensional configuration, that is, the enantiomers are mirror images of each other. For disparlure, the (+) enantiomer is the biologically



Feather-like antennae enable the male gypsy moth to locate a source of pheromone.

active form produced by the female moth to attract the male. In gypsy moth projects, both forms of disparlure are used: the (+) disparlure and a 50:50 mixture of the (+) and (–) forms of the molecule (called a racemic mixture). Racemic disparlure is the form that is used as a mating disruptant. The (+) disparlure is used as a lure in milk carton and delta traps. More information on these two uses of disparlure is presented in *appendix A*.

Hazard Identification

In acute toxicity tests disparlure was not toxic to mammals (IBT 1972), birds (USDI Fish and Wildlife Service 1975), or fish (USDI Fish and Wildlife Service 1972). One field study showed no effect of disparlure applications on the degree the wasp *Ooencyrtus kuvanae* parasitizes gypsy moth eggs (Brown and Cameron 1979). No studies were found in the published literature on the effects, if any, of disparlure on aquatic ecosystems.

When applied in flakes to a woodland, disparlure concentration in the air dropped gradually over 34 days to between 1.5 and 15.5 percent of that measured in the first 24 hours. At usual application rates this level (0.04 ng/m^3) is estimated to be near the threshold at which gypsy moths can detect it, as it is within an order of magnitude of the threshold concentration at which many species of insects respond to pheromones (Caro and others 1981).

Exposure Assessment

Dispersion of disparlure in flakes or beads after aerial application was estimated to be similar to that for diflubenzuron and *B.t.k.*, with most depositing in the canopy and a smaller amount penetrating to the forest floor. Because of its low toxicity to vertebrates, the sparse data on its toxicity to invertebrates, and its apparent specificity to male gypsy moth adults, an extensive quantitative exposure assessment was not performed.

Instead, disparlure residues were estimated based on theoretical deposition rates onto a flat surface. Since this model assumes no vegetative cover it overestimates the disparlure residues expected in a forest and represents a worst-case scenario. Given the registered application rate of 30.4 g/acre, the expected disparlure residue is estimated to be 0.741 µg/cm^2.

Risk Characterization

A quantitative assessment of risk from disparlure was not conducted because of its low toxicity to vertebrates and specificity to gypsy moth.

As used in mating disruption or mass trapping treatments, disparlure is not likely to cause changes in nontarget organisms, forest condition, water quality, microclimate, or soil productivity and fertility.

Effects Due to the Sterile Insect Technique

The sterile insect technique involves the release of totally sterile male pupae, male pupae that have received a substerilizing dose of radiation, or sterile F_1 egg masses that were produced from mating of substerilized males with nonirradiated females. Treatment effects of releasing totally sterile male pupae occur only in the year of treatment while the treatment effects of releasing substerilized male pupae or sterile F_1 egg masses occur over 2 years.

None of the three approaches has any known effects on other organisms, or on forest condition, water quality, microclimate, or soil productivity and fertility. Use of sterile F_1 egg masses or substerilized male pupae could add a sufficient number of gypsy moth caterpillars to the treatment area to cause some tree defoliation. Defoliation would occur, however, only in the year that the sterile caterpillars are released, and most likely would be light. Effects due to this defoliation would be negligible.

Chapter 4, Part C
Environmental Consequences of Alternatives

Contents

Part C Environmental Consequences of Alternatives

This part of *chapter 4* presents information about what could happen to the environment by the year 2010 if the alternatives are implemented. Consequences are presented by alternative at the national level and are general. They consider the gypsy moth and all of the treatments available for use with each alternative. This part provides a basis for developing an understanding about differences between alternatives.

Consequences of each alternative pertain only to the geographic area of the United States where strategies would be implemented. In other words, effects that result from implementing suppression apply only to the generally infested area in the eastern United States. Effects that result from implementing eradication apply only to the uninfested area in the southern, central, and western States for the European strain of the gypsy moth; and to the entire country for the Asian strain. Effects that result from implementing slow the spread apply only to the transition area between the generally infested and uninfested areas.

Conditions Common to All Alternatives

The gypsy moth is not a universal problem. Under all of the alternatives, in portions of the generally infested area, gypsy moth populations will be too low to cause any noticeable effects. For example, each year between 1981 and 1994 no gypsy moth outbreaks occurred on 87.4 to 99.2 percent of the generally infested area.

In all of the alternatives the gypsy moth will defoliate some areas in the generally infested area but many times no action would be taken. From 0.5 to 12.4 percent of the generally infested area was defoliated but not treated between 1981 and 1994.

Effects due to treatments from implementing alternatives 2 through 6 will occur only in areas that are treated. Annual suppression treatment areas totaled between 0.3 and 1.0 percent of the generally infested area from 1981 to 1994.

The environmental consequences of implementing an alternative depend largely on the particular treatments that could be used to suppress, eradicate, or slow the spread of the gypsy moth. (See *table 2-1* for treatments available by alternative.) Factors that influence the effects of the treatments include how much is used, how often it is applied, and the physical and biological attributes of the treatment area. These factors vary from site to site.

Project-level environmental consequences of individual treatments are beyond the scope of this environmental impact statement and must be determined through site-specific environmental analyses, including determining the potential for effects on endangered and threatened species.

Under all alternatives Federal agencies, States, American Indian tribes, local governments, and individuals may take action to control the gypsy moth and not participate in the national gypsy moth management program. The U.S. Department of Agriculture (USDA) would have no authority in those situations. Therefore, the environmental consequences of those actions were not analyzed for this environmental impact statement.

In compliance with Executive Order 12899, environmental justice issues have been considered in the analysis. The scoping and public participation process focused on including as many interested parties as possible. This environmental impact statement has been summarized and made as clear as possible. Impacts from the gypsy moth cut across boundaries such as race, ethnicity, income, geography, and culture. Actions proposed for gypsy moth management are based upon biological, ecological, and human health principles.

No changes to human populations in the affected States, including minority and low-income populations, are expected from implementing any of the alternatives. Rural and urban composition, size of metropolitan areas, and jobs in broad employment

areas such as agriculture, manufacturing, and service industries, are not expected to be affected. Likewise, wetlands, floodplains, prime farmland, and rangeland are not expected to be affected by any of the alternatives proposed.

Consequences of Alternatives

Flow diagrams outline the expected consequences of each alternative by the year 2010, after it has been implemented for 15 years (*fig. 4-2* through *fig. 4-7*). A brief explanation of how the numbers in the flow diagrams were derived can be found in *chapter 2* under Expected Future Conditions.

The estimates in the diagrams can be compared with actual figures from 1994: the generally infested area was 156 million acres (63 million ha); the transition area was 50 million acres (20 million ha); the uninfested area was 2,057 million acres (833 million ha); an average of 3.6 million acres (1.5 million ha) were defoliated yearly between 1981 and 1994; and outside the generally infested area 42 isolated infestations were eradicated.

Each diagram is set up as follows:

- **Area location and size**—Beginning at the left of the diagrams, the three main arms represent geographic areas of the country that differ in infestation status (generally infested area, transition area, uninfested area).
- **Gypsy moth population levels**—The gypsy moth is not always a problem in the generally infested area, and its presence is not always immediately detected in the transition and uninfested areas. Moving from left to right, each arm of the diagram splits into at least two branches in the area of gypsy moth population levels, to represent these different possibilities.
- **USDA response**—Regardless of gypsy moth population levels, no treatment by the USDA is always an option. Arms of the diagram branch further in the area of USDA response when an alternative allows the option for treatment.
- **Consequences and area affected**—The diagram shows, by the year 2010, consequences of treatment or no treatment by the USDA—by number of acres involved, whether effects are expected, and whether they would be due to the gypsy moth or to treatment. Acreages do not reflect action or no action by States or individuals that may be taken without cooperation in the national gypsy moth management program. The estimated area affected by eradication of the Asian gypsy moth in the generally infested area is unknown and not included in the projection. Effects due to the gypsy moth, insecticides, and noninsecticidal treatments are summarized in *part A* of this chapter for human health and safety, and in *part B* for ecological factors.

Consequences of Alternative 1

Under alternative 1 no suppression, eradication, or slow-the-spread projects would be conducted. Therefore, environmental consequences of alternative 1 would be attributable to gypsy moth caterpillars or to the damage they cause (*fig. 4-2*).

Effects on Infestation Status

Under alternative 1, 89.9 percent of the generally infested area would support innocuous gypsy moth populations, and gypsy moth outbreaks would cause defoliation over the remaining 10.1 percent of the area. This figure includes defoliation that would be possible where isolated infestations establish and become generally infested areas between 1994 and 2010. The size of the generally infested area would continue to increase.

Ecological Effects

The level and duration of a gypsy moth outbreak and the interval between outbreaks are key variables that determine ecological effects due to the gypsy moth. Higher population density, longer outbreak duration, and repeated outbreaks have greater effects than do low population densities, shorter outbreak duration, and a single outbreak.

Consequences of Alternative 1 (no suppression, no eradication, no slow the spread)

Area location and size	Gypsy moth population levels	USDA response	Consequences and area affected
Generally infested area 685 million acres	Innocuous populations	No treatment	No effects on 616 million acres
	Outbreaks and defoliation	No treatment	Effects due to gypsy moth on 69 million acres
Transition area 1,037 million acres	No detectable populations	No treatment	No effects on 1,032 million acres
	Detectable populations	No treatment	Gypsy moth spreads, effects due to gypsy moth begin to be noticeable on 5 million acres
Uninfested area 541 million acres	No gypsy moths present	No treatment	No effects on 541 million acres
	76 isolated infestations	No treatment	Infestations may establish

Figure 4-2. Conditions shown for alternative 1 are annual projections in the year 2010.

Nontarget Organisms

When gypsy moth populations reach outbreak levels, defoliation and subsequent tree mortality can dramatically change wildlife habitats on a local scale. Impacts on wildlife on a larger scale (national, regional, or State), however, are subtle, gradual, and may be noticeable only after many years or even decades (if at all). Only about 10.1 percent of the generally infested area would be defoliated in any given year.

In the areas that are defoliated by the gypsy moth, wildlife population shifts and changes in reproductive rates and mortality rates would influence local populations for 1 to 2 years. The ability of a forested area to support populations of wildlife will change as a result of changes in forest condition due to defoliation. In general, with more varied habitat conditions due to gypsy moth defoliation, a higher number of species can be expected (DeGraff and others 1992). As habitat structure becomes more complex after heavy defoliation, more niches become available, and the coexistence of a greater number of plant and animal species is possible (Tomblin 1994). Short- and long-term changes in several nontarget species are shown for moderate defoliation in *table 4-3* and for heavy defoliation in *table 4-4*.

Heavy defoliation by the gypsy moth in critical habitat areas for fish, wildlife, and plant species protected by the Endangered Species Act of 1993 can degrade habitat and thereby jeopardize their continued existence. For example, the Delmarva fox squirrel (*Sciurus niger cinereus* Linnaeus) requires an oak habitat and acorns to thrive, and defoliation by the gypsy moth reduces acorn abundance and leads to mortality of oak trees.

Effects on aquatic organisms due to heavy defoliation by the gypsy moth are expected to be greater in upstream areas characteristic of undeveloped areas. For example, heavy defoliation may result in loss of trout populations in marginal trout streams in the short term, although large scale failure of trout populations is not likely (USDA Forest Service 1994f). Slow moving or still water habitats will be less affected by defoliation.

Forest Condition

Forests are affected by the gypsy moth only when populations of the insect reach defoliating levels. The effects of defoliation vary widely depending upon the extent of defoliation, the vulnerability of the trees, and the resulting mortality. Indicators of forest condition include tree mortality (vulnerability), numbers of tree species and their abundance, stand structure, mast production, tree diameter growth, tree quality, numbers of shrub and herbaceous plant species, susceptibility to fire, and stage of forest succession.

Although only a small amount (3.5 percent) of the generally infested area is subject to the damaging effects of defoliation annually, forests are affected by defoliation that occurs over decades. In forest stands with susceptible tree species, the types and numbers of species conceivably would change as a result of heavy defoliation caused by the gypsy moth under alternative 1. In addition, forests in the uninfested area may be subject to defoliation by the gypsy moth if isolated infestations become established.

Not all forests would be affected by the gypsy moth, and not all affected forests would be affected in the same way. In general, forest stands subjected to repeated heavy defoliations would sustain at least 15-35 percent tree mortality after the initial outbreak, and more after repeated outbreaks. The extent of mortality will depend on species diversity and abundance, duration of defoliation, and intensity of defoliation (Fosbroke and Hicks 1989). Some marginal forest stands (on low productivity sites; at high elevation; with thin, dry soils) could convert to shrubland-grassland as a result of high mortality of trees in the canopy.

Forest stands that are heavily defoliated (over 60 percent) would likely exhibit the following characteristics:

- Production of hard mast would decrease (Gottschalk 1990b), and soft mast would increase. As changes in mast production affect seed sources for plant regeneration, species present in a stand may change.
- Forest stands would lose shorter subdominant trees, becoming more one-storied. In some situations this change could provide benefits

to the stand similar to those from intentional thinning. When these changes are due to defoliation, however, the commercial value of the trees that are killed would be lost, and they may not have been those best suited for removal (Kucera and Niskala 1991).

- Shade-tolerant species and species less susceptible to the gypsy moth would become more numerous (Gansner and others 1983). Values of commercial timber and wildlife habitat will change.
- Growth rates of shrubs and herbaceous plants would increase, favoring some wildlife species and vegetation regeneration. If heavy defoliation occurs in consecutive years, tree mortality would increase. As a result, fire hazard would increase due to increased fuel from standing dead trees and downed wood (Gottschalk 1990a).
- Losses in timber volume and value may be significant in early years of outbreaks, although these losses may be offset by a long-term increase in growth (Gansner and others 1983). Numbers of tree species would increase in most defoliated forests (Quimby 1993).

Water Quality

In most instances defoliation by the gypsy moth would have little effect on water bodies (Corbett and Lynch 1987, Grace 1986). Water quality is affected to the degree that heavy defoliation occurs along small streams. Effects are associated primarily with nutrient input from frass and leaf fragments, increased water yield, and chemical changes in runoff and leached water in defoliated stands (Corbett 1992). Heavy defoliation of streamside vegetation and the adjacent watershed may reduce the acid neutralizing capacity in some Appalachian headwater streams, and cause nitrate levels and acidity to increase. If drinking water supplies are affected, water purification treatments may be needed.

Microclimate and Soil

Moderate to heavy defoliation would elevate temperatures and increase soil moisture over the short term. Soil decomposition and mineralization, as well as biological productivity of plants will increase in the short term.

Human Health and Safety

During an outbreak, some people may experience skin irritation, caused by an allergic reaction to gypsy moth hairs (Aber and others 1982, Anderson and Furniss 1983, Tuthill and others 1984), particularly from first instar caterpillars. Affected individuals may seek medical attention.

Although not as well documented, irritation to eyes and to the respiratory tract are also possible, but there is no basis to indicate that respiratory effects are life threatening or require hospitalization (Perlman 1965, Shama and others 1982). These possible health effects do not suggest that exposure to the gypsy moth poses an imminent hazard or a public health concern; effects generally would be short-lived and be mild. The portion of the population most at risk would be young children who spend more time outdoors than most adults (Tuthill and others 1984).

During outbreaks roads and walkways can, in rare occasions, become slippery from masses of caterpillars and frass, causing hazardous conditions for automobiles and pedestrians (USDA 1985). Dead trees resulting from repeated defoliations and secondary pathogens pose a threat from falling limbs.

Social and Economic Effects

In 1990, about 91 million people lived in the generally infested area, and at least another 46 million people lived in the area that is expected to be generally infested by the year 2010 (USDC 1993). These people are most likely to experience a gypsy moth outbreak, or at least see some level of noticeable defoliation. People living in the uninfested and transition areas would not be as likely to experience effects due to the gypsy moth or defoliation because the infestations are relatively few and small, and gypsy moth populations are at low levels. As the generally infested area expands and if isolated infestations become established, people who now live in the uninfested and transition areas would be exposed to the gypsy moth and its effects.

Droppings from gypsy moth caterpillars can litter walkways.

Perceptions and Behaviors

Gypsy moth outbreaks and new infestations can disrupt people's lives. Some people have an emotional response, such as aggravation of entomophobia (fear of insects) caused by large numbers of caterpillars. Some people may be extremely anxious about outbreaks (National Gypsy Moth Management Group 1991, Williams 1982).

People in urban areas, who have to deal with the caterpillars in spring during outdoor activities, generally view the gypsy moth as a nuisance (Miller and Lindsay 1993a). People may spend less time in outdoor activities to avoid contact with gypsy moths (Moeller and others 1977). People in undeveloped areas who have jobs tied directly to natural resources, recreation, and tourism and spend more time outdoors may view the gypsy moth both as a nuisance and as a threat to their income.

Residential and business property owners, fearing reduced property values with the loss of ornamental vegetation, may resort to hiring private contractors to treat their properties with a variety of insecticides (Marler and McCrea 1977). Owners and managers of larger forest areas may also contract with insecticide applicators or, in some cases, sell the trees for timber.

People moving from infested areas would continue to move gypsy moth egg masses, caterpillars, and adult moths into the uninfested area. This artificial spread could accelerate expansion of the area where gypsy moths are established, unless State regulatory programs are sufficient to avert it.

Economics

Gypsy moth outbreaks trigger a variety of economic responses. Property owners in the generally infested area would incur costs during and after gypsy moth outbreaks. These include costs for treating outbreaks, increased maintenance, and reductions in property values (Moeller and others 1977). Some of these costs will be due to removing the caterpillars or their waste, washing or repainting buildings, and removing dead or dying trees. Removal and replacement of dead ornamental trees is another cost that property owners may incur.

Trees lost as a result of gypsy moth related mortality are of particular concern in urban areas (Ticehurst and Finley 1988). Loss of the cooling effects of shade trees may result in an increasing use of air conditioning and thus an increase in energy costs to homeowners and businesses (USDA 1985). Losses of trees on larger properties may represent a loss of revenue that was planned from the sale of trees as timber. Economic losses would occur in recreation and tourism businesses associated with forest settings, as people avoid areas with gypsy moth outbreaks (Moeller and others 1977).

Under alternative 1 State gypsy moth control programs would be reduced, reducing income to companies and employees who contract with Federal and State agencies to treat the gypsy moth. Without USDA financial assistance, costs to the States could be higher. If regulatory activities conducted by the States, such as restricting interstate commerce of forest products and other goods, are insufficient, the expansion of the gypsy moth into the uninfested area will accelerate.

In urban areas defoliation can result in costs to property owners.

Recreation

Gypsy moth outbreaks have the potential for many effects on recreation. Enjoyment of recreational activities would be reduced during late spring to early summer under alternative 1. Outdoor activities may be curtailed by people who do not want to be bothered by the presence of caterpillars. Recreational use of private properties, commercial recreation areas, and public recreation areas would be reduced (Moeller and others 1977). Some people may delay their recreation plans until after the caterpillars are gone.

Heavy repeated defoliation that is followed by tree mortality can change the character of a forest or recreation area so that the same recreational experience is not available. Defoliation and longer-term tree mortality have esthetic impacts that reduce the quality of outdoor experiences, as well as esthetic impacts to home and business properties. Esthetic damage was one of the most frequent reasons given by individuals for their willingness to pay for gypsy moth control (Miller and Lindsay 1993b). Defoliation can result in fewer visits to parks and resort areas during times when people expect trees to have foliage (Moeller and others 1977). Under alternative 1 managers of wilderness, wild and scenic rivers, national parks, and other special value areas that provide unique recreational experiences would not have the option to participate in the national gypsy moth management program.

Consequences of Alternative 2

Under alternative 2 suppression projects could be conducted in the generally infested area. In areas that would be treated, effects on the environment would be associated with application of *B.t.k.*, diflubenzuron, or the gypsy moth nucleopolyhedrosis virus—the insecticides available for use in suppression projects. Effects of treatments would be local, and historically (1981-1993) have occurred on 0.3 to 1.0 percent of the generally infested area in any one year.

In parts of the generally infested area with outbreaks that are not treated, effects would be the same as those described under alternative 1. In the uninfested area, isolated infestations may eventually become established. In the transition area, gypsy moth populations will build and continue to spread at a rate of about 13 miles (21 km) per year (*fig. 4-3*).

Effects on Infestation Status

Under alternative 2, 89.9 percent of the generally infested area would support innocuous gypsy moth populations. Suppression could be conducted, however, to prevent or minimize defoliation over the remaining 10.1 percent of the area. This figure includes suppression that would be conducted where isolated infestations become generally infested areas between 1994 and 2010. The size of the generally infested area would continue to increase.

Consequences of Alternative 2 (suppression)

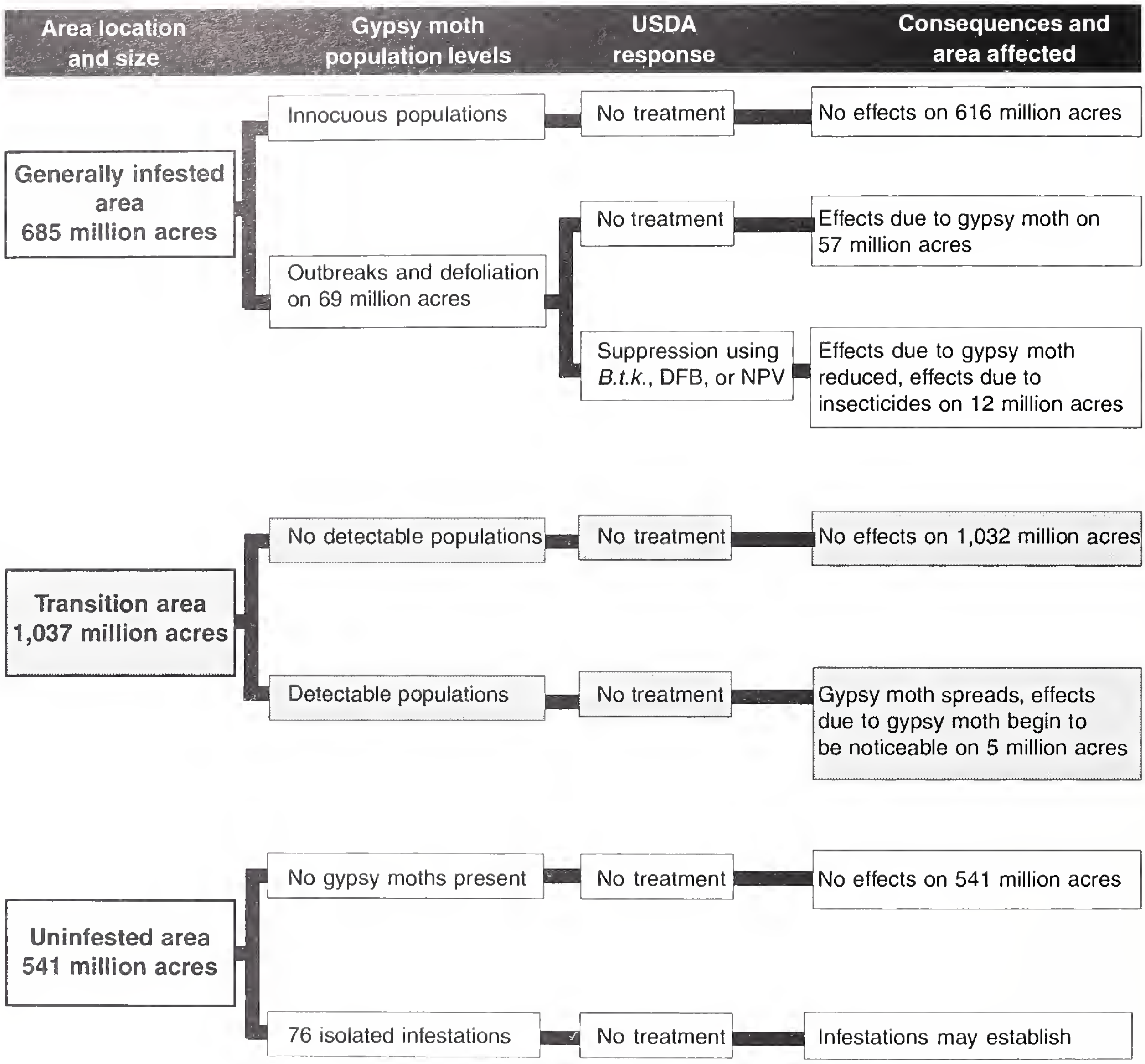


Figure 4-3. Conditions shown for alternative 2 are annual projections in the year 2010.

Ecological Effects

Nontarget Organisms

Individual treatments can have numerous effects on nontarget species of wildlife (see the sections on *B.t.k.*, diflubenzuron, and nucleopolyhedrosis virus [Gypchek] in *part B* of this chapter and *appendix G*). Effects vary by site depending on choice of treatment type, application method, and environmental conditions.

Populations of endangered and threatened species and plants, and their critical habitat would be protected from damaging effects of the gypsy moth to the degree suppression treatments are successful. Lepidopterans, however, including endangered and threatened species, such as the Karner blue butterfly (*Lycaeides melissa samuelis* [Edwards]), could be directly affected by treatments (Haack 1993). Other endangered species may be indirectly affected by treatments used in suppression projects. For example the Virginia big-eared bat may have to forage for food over a larger than normal area if its primary prey (moths) are depleted in its usual foraging area.

Forest Condition

In treated areas suppression reduces the potential for changes in forest condition that would otherwise be caused by heavy gypsy moth defoliation and subsequent tree mortality. These effects would be confined to treatment areas and would not be apparent on national, regional, or Statewide scales. In situations with high gypsy moth populations where suppression treatments are not used, however, effects on forest condition would be similar to those described under alternative 1.

In the uninfested area, forests and trees would be exposed to gypsy moths as isolated infestations become established. In the transition area populations of gypsy moths would build to potentially defoliating levels and spread.

Water Quality

Suppression projects would not be expected to have direct effects on water quality; however, indirect effects would be possible (*part B* of this chapter and *appendix G*). The amount of diflubenzuron that reaches surface water has the potential to differ in developed and undeveloped areas, because surfaces that are impervious to water (asphalt, concrete) affect the amount of runoff and the amount of diflubenzuron it contains. Effects are short-lived (usually less than one season), however, even with multiple applications, and may appear only in water bodies in or near project areas. Effects on water quality that occur as a result of high populations of gypsy moths or heavy defoliation would be reduced where suppression is conducted. In areas where suppression is not conducted impacts on water quality would be similar to those described under alternative 1.

Microclimate and Soil

Changes in microclimate, and soil productivity and fertility are not expected as a result of suppression under alternative 2.

Human Health and Safety

Suppression projects that use *B.t.k.* may result in some people having minor irritations of the skin, eyes, or respiratory tract if they are directly exposed to the spray; but the prevalence of these effects is expected to be low. These effects would be similar to but less severe than those caused by exposure to the gypsy moth. Adverse health effects would not be likely, even in immunocompromised individuals (Noble and others 1992). Workers in suppression projects would have a much greater chance for exposure than would the general public. Following safe working practices greatly reduces the risk of worker exposure to insecticides.

The gypsy moth virus product, Gypchek, has not been widely used, and epidemiology data are not available. Studies on animals suggest that its potential to cause adverse effects in people is low (Cannon Laboratories, Inc. 1976a; Litton Bionetics, Inc. 1975a,b). Since Gypchek is composed primarily of ground-up gypsy moth parts, health effects from suppression projects that use Gypchek conceivably could be similar to those experienced by people who come in contact with gypsy moth caterpillars.

Diflubenzuron presents no substantial risks to the general public or workers, either during routine suppression projects or from accidents. At extreme levels of exposure an increase in certain blood pigments might be detectable but not clinically

significant. Conservative estimates of cancer risks are negligible—less than one in 1 million for diflubenzuron and the breakdown product 4-chloroaniline.

Aircraft accidents may occur in connection with aerial application of insecticides, and incidental automobile accidents may result from distraction caused by the low-flying aircraft.

Suppression would reduce gypsy moth populations thereby reducing the chance of human exposure to the insect and the resulting health effects described under alternative 1.

Social and Economic Effects

Perceptions and Behaviors

Alternative 2 would reduce disruption to people's lives caused by the gypsy moth. A higher proportion of suppression treatments would be conducted in suburban and residential areas than in undeveloped areas. Property values would be maintained in areas that are treated to reduce heavy gypsy moth defoliation (Moeller and others 1977). In treated areas, people would not need to adjust their time spent on outdoor activities to avoid contact with the gypsy moth. Livelihoods that depend on natural resources, recreation, and tourism would be less threatened than without suppression (Moeller and others 1977). Management plans for forest properties will not be disrupted by gypsy moth infestations. People relocating from the generally infested and transition areas will continue to move the gypsy moth into the uninfested area, accidentally causing isolated infestations that may become established populations. Suppression may, however, reduce the chance for people to move the gypsy moth.

Stress or anxiety may be associated with gypsy moth infestations and be exacerbated by disputes about appropriate approaches for dealing with the pest (National Gypsy Moth Management Group 1991, Williams 1982). The use of insecticides in suppression projects may create a situation that some people will neither understand nor approve. People who fear exposure to insecticides may be concerned. Apprehension and fear could be aggravated by prominent media coverage of either the insect or insecticides. One study in Vancouver, British Columbia, demonstrated an initial period of public concern before the start of a gypsy moth treatment program (Noble and others 1992), but showed a sharp decline in reports of human health concerns after the treatments began. The study concluded that human health complaints as a result of treatment were no more common in people living inside the treatment area than outside the treatment area.

Some aspects of gypsy moth treatments can disrupt people's activities while treatments are in progress. Aerial application of insecticides is usually conducted in the morning, although afternoon and early evening applications are possible if weather is favorable. Some people will have emotional responses or anxiety caused by the presence of low flying aircraft. A majority of individuals who initially objected to control measures wanted some form of control after they experienced a gypsy moth outbreak (Marler and McCrea 1977).

Economics

People's willingness to pay for gypsy moth control suggests that gypsy moth infestations are regarded as undesirable (Miller and Lindsay 1993a,b). Under alternative 2, suppression within the

Spraying to control the gypsy moth is commonly done by helicopter.

generally infested area would reduce costs to property owners for cleanup of caterpillars, their waste, and dead or dying trees during and after gypsy moth outbreaks. Costs of tree removal and replanting in residential and urban areas are avoided with suppression of gypsy moth populations. Ornamental and native trees close to homes and businesses will continue to provide cover and shade resulting in efficient cooling in the summer months reducing the cost of air conditioning. Property owners and managers of commercial woodlands will not be faced with the decision to market timber prematurely or lose the value of the trees. Recreation and tourist businesses associated with forest settings would not have reduced visitation due to the presence of gypsy moths or esthetic impacts.

Regulatory activities conducted by APHIS, such as restrictions on interstate commerce of forest products and other goods, would continue. Because organic farmers are not able to certify and market their crops as chemical free if they are exposed to diflubenzuron, mitigation measures or modified procedures such as using *B.t.k.* or Gypchek, would need to be taken to reduce or eliminate this effect.

Federal and State agencies would be able to receive USDA assistance. State gypsy moth suppression programs would continue on a cost-share basis. Private companies would have the opportunity to contract with Federal and State agencies for work on suppression projects.

Recreation

In treated areas opportunities for recreational activities would be maintained throughout the year. Heavy defoliation and tree mortality would be avoided, and forest esthetics important to recreation would be maintained (Miller and Lindsay 1993b). In treated areas people would not have to change their recreation use patterns to avoid gypsy moth outbreaks (Moeller and others 1977). They may, however, change their use patterns to avoid areas being sprayed.

Managers of wilderness, wild and scenic rivers, national parks, and other special value areas that provide unique recreational experiences would be able to participate in the national gypsy moth management program.

Consequences of Alternative 3

Under alternative 3 eradication projects could be conducted in the uninfested area and—for the Asian strain—in the generally infested area. Effects associated with eradication treatments would be apparent only at the local level, be limited to the areas treated, and be associated with application of *B.t.k.*, diflubenzuron, Gypchek, mass trapping, mating disruption, or the sterile insect technique. In areas not treated effects due to the gypsy moth would be the same as those described under alternative 1 (*fig. 4-4*).

Effects on Infestation Status

Under alternative 3, 95.4 percent of the generally infested area would support innocuous gypsy moth populations, and gypsy moth outbreaks would cause

Treatment can maintain the esthetics in recreation areas.

defoliation over the remaining 4.6 percent of the area. The size of the generally infested area would continue to increase. Isolated infestations would be eradicated, preventing them from becoming established and adding to the size of the generally infested area.

Ecological Effects

Nontarget Organisms

Using *B.t.k.* and diflubenzuron could have greater effects on nontarget species of wildlife in areas treated under alternative 3 than would be expected under alternative 2. Effects could be greater because two to three applications are often required for eradication compared with one for suppression. Multiple applications of diflubenzuron would present less risk to organisms in habitats where diflubenzuron does not persist, such as streams, ponds, and soil. Because *B.t.k.* is not persistent, multiple applications within the same year would prolong the period *B.t.k.* is present. Lepidopterans present during the initial treatment period would be at increased risk, as would additional lepidopteran species that hatch throughout the extended treatment period. The area treated is typically smaller for eradication projects than for suppression projects, therefore, the total number of organisms affected by an eradication project could be less than that affected by a suppression project.

There are no known direct effects on nontarget organisms as a result of using the gypsy moth virus, mass trapping, mating disruption, or the sterile insect technique.

By preventing gypsy moth populations from becoming established, eradication would reduce effects on nontarget species due to the gypsy moth.

Forest Condition

There are no known direct effects on forest condition as a result of any of the treatments used in eradication projects. Even though the sterile insect technique increases gypsy moth populations temporarily, subsequent defoliation is expected to be negligible. Eradication eliminates gypsy moth infestations, thereby reducing the potential for a change in forest condition due to the gypsy moth.

Water Quality

Eradication projects are not expected to have direct effects on water quality. Diflubenzuron affects stream invertebrates that process detritus and feed on algae. Declines in detrital decomposition rates and increases in algae could occur; however, they have not been demonstrated in field studies. Although multiple applications commonly used in eradication projects prolong the period of exposure, treatment areas typically are smaller than those in suppression projects. Other treatments available for use in eradication projects will not affect water quality.

Human Health and Safety

Effects on human health from eradication projects that use *B.t.k.*, diflubenzuron, or Gypchek will be the same as those described under alternative 2. Multiple treatments in one season could result in greater exposure.

Risks to human health from exposure to disparlure are low. The Human Health Risk Assessment (*app. F*) concluded that levels of human exposure to disparlure in mass trapping and mating disruption are far below levels that did not cause toxic effects in experimental animals. Male gypsy moths may be attracted to individuals who have been exposed to disparlure. It persists in the body and may attract moths for years, and can be a nuisance (Cameron 1981, 1983). The likelihood of this effect is greater for those who work with disparlure than for the general public, whose exposure is minimal.

Under conditions of normal use and handling, DDVP (dichlorvos) used in mass trapping presents no significant toxic or cancer risks to project workers. If DDVP strips are not handled properly, workers may experience mild and reversible neurological effects. People who tamper with traps and handle DDVP strips are also at risk. The severity of effects depends on the duration of exposure. Severe toxic effects are possible but unlikely.

The sterile insect technique, when used in eradication projects, increases gypsy moth populations temporarily, thereby increasing the risk of exposure. This treatment is used in areas with such low gypsy moth populations, however, that

Consequences of Alternative 3 (eradication)

Area location and size	Gypsy moth population levels	USDA response	Consequences and area affected
Generally infested area 305 million acres	Innocuous populations	No treatment	No effects on 291 million acres
	Outbreaks and defoliation	No treatment	Effects due to gypsy moth on 14 million acres
Transition area 71 million acres	No detectable populations	No treatment	No effects on 70.5 million acres
	Detectable populations	No treatment	Gypsy moth spreads, effects due to gypsy moth begin to be noticeable on 0.5 million acres
Uninfested area 1,887 million acres	No gypsy moths present	No treatment	No effects on 1,886.48 million acres
	263 isolated infestations	Eradication using multiple applications of *B.t.k.*, DFB, or NPV	New infestations eliminated, effects due to insecticides on 484,000 acres
		Eradication using mass trapping, mating disruption, or sterile insect technique	New infestations eliminated on 36,000 acres

Figure 4-4. Conditions shown for alternative 3 are annual projections in the year 2010.

increases in exposure and any subsequent effects should be insignificant.

Aircraft accidents may occur in connection with aerial application of insecticides, and incidental automobile accidents may result from distraction caused by the low-flying aircraft.

Eradication prevents establishment of isolated infestations thereby reducing the risk of human exposure and resulting health effects due to the gypsy moth caterpillar, which are described under alternative 1.

Social and Economic Effects

Perceptions and Behaviors

Alternative 3 would reduce disruption to people's lives caused by the gypsy moth. Because people are responsible for artificially spreading the gypsy moth to the uninfested area of the United States, a higher proportion of eradication treatments would be conducted in typical suburban and forested residential areas, which have greater numbers of people than do undeveloped areas. People relocating from the generally infested and transition areas would continue to move the gypsy moth into the uninfested area. These isolated infestations would be eradicated.

Under alternative 3, where eradication projects are conducted, the perceptions and behaviors would be similar to those described for suppression projects under alternative 2. Disturbance, such as low-flying aircraft, and the apprehension and fear people may associate with treatment, such as occurred in a gypsy moth eradication project in Vancouver, British Columbia (Noble and others 1992), are more likely with multiple treatments. Apprehension would likely be less at the time of the second application, because people will have already experienced a treatment project. People concerned about the use of insecticides are less likely to object to eradication projects that use mass trapping, mating disruption, or the sterile insect technique.

Economics

Eradication would prevent isolated gypsy moth infestations from becoming established, spreading, and becoming generally infested. Under alternative 3, eradication project costs would be shared by Federal and State agencies. These costs would offset the economic consequences associated with the gypsy moth described under alternative 1, and possible suppression costs described under alternative 2. *B.t.k.*, Gypchek, and the noninsecticidal treatments are options for eradication that will not jeopardize certification of chemical-free crops grown by organic farmers.

Federal and State agencies can be authorized to spend funds in cooperative eradication projects. State gypsy moth eradication programs would continue on a cost-share basis. Private companies would have the opportunity to contract with Federal and State agencies for work on eradication projects.

Recreation

Eradication would prevent isolated gypsy moth infestations from becoming established populations. Therefore, the recreational consequences described under alternative 1 associated with the gypsy moth and defoliation are avoided under alternative 3. Consequences on recreation expected under this alternative are those described under alternative 2.

Eradication projects would probably be more disruptive to people in recreation areas than would suppression treatments, because of the need to use two or three applications of insecticides for eradication. Use of mass trapping, mating disruption, or the sterile insect technique—where practical—will lessen the disruption.

Consequences of Alternative 4

Under alternative 4 suppression and eradication projects could be conducted. This alternative represents the gypsy moth management program that has been in place since the 1985 environmental impact statement was published. One difference in the proposed program is that infestations of the Asian strain could be eradicated in the generally infested area (*fig. 4-5*).

Under alternative 4, 95.4 percent of the generally infested area would support innocuous gypsy moth populations. Suppression could be conducted, however, to prevent or minimize defoliation over the remaining 4.6 percent of the area. The size of the generally infested area would continue to increase. Isolated infestations would be eradicated, preventing

them from becoming established and adding to the size of the generally infested area.

Suppression and eradication projects have been successfully conducted for years. Ecological, human health and safety, and social and economic effects resulting from those projects are consistent with those projected for suppression and eradication in this environmental impact statement. Under alternative 4, environmental effects would be similar to those described under alternative 2 for suppression and under alternative 3 for eradication.

Consequences of Alternative 5

Under alternative 5 eradication projects could be conducted. Slow-the-spread projects could be conducted in the transition area (*fig. 4-6*).

Under alternative 5, 95.6 percent to 96.1 percent of the generally infested area would support innocuous gypsy moth populations, and gypsy moth outbreaks would cause defoliation over the remaining 3.9 to 4.4 percent of the area. Slow the spread could be conducted in the transition area and should reduce the growth of the generally infested area. Isolated infestations would be eradicated, preventing them from becoming established and adding to the size of the generally infested area.

Since the same treatments are available in both strategies in this alternative, the same environmental consequences are expected for either strategy. One difference is the geographical area where treatments would be applied and, therefore, where the consequences would occur. Environmental effects that result from eradication projects in this alternative would be similar to those described under alternative 3. Environmental consequences due to slow-the-spread projects that use insecticides would be similar to those described for suppression projects under alternative 2, because slow-the-spread treatments also typically involve large treatment areas and one application. Environmental consequences of slow-the-spread projects that use noninsecticidal treatments would be similar to those described for those treatments under alternative 3.

Treatment of low level populations is only one factor that affects the rate of gypsy moth spread. Precipitation, foliage expansion, and wind conditions also play a role. Under the variety of conditions expected, the slow-the-spread strategy would reduce the rate of spread by an estimated 25-75 percent of the historic rate (13 mi or 21 km per year), by the year 2010.

Consequences of Alternative 6

Under alternative 6 suppression, eradication, and slow the spread projects could be conducted (*fig. 4-7*).

Under alternative 6, 95.6 to 96.1 percent of the generally infested area would support innocuous gypsy moth populations. Suppression could be conducted, however, to prevent or minimize defoliation over 0.5 to 0.7 percent of the area. Gypsy moth outbreaks would cause defoliation over the remaining 3.4 to 3.7 percent of the area. Slow the spread would be conducted in the transition area and should reduce the growth of the generally infested area. Isolated infestations would be eradicated, preventing them from becoming established and adding to the size of the generally infested area.

Environmental consequences expected with suppression in this alternative are the same as those described under alternative 2. Consequences expected as a result of implementing eradication are the same as those described under alternative 3, and consequences expected with slow the spread are the same as those described under alternative 5.

Cumulative Effects of Alternatives

Cumulative effects are defined as "... the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR 1508.7, p. 28).

Consequences of Alternative 4 (suppression and eradication)

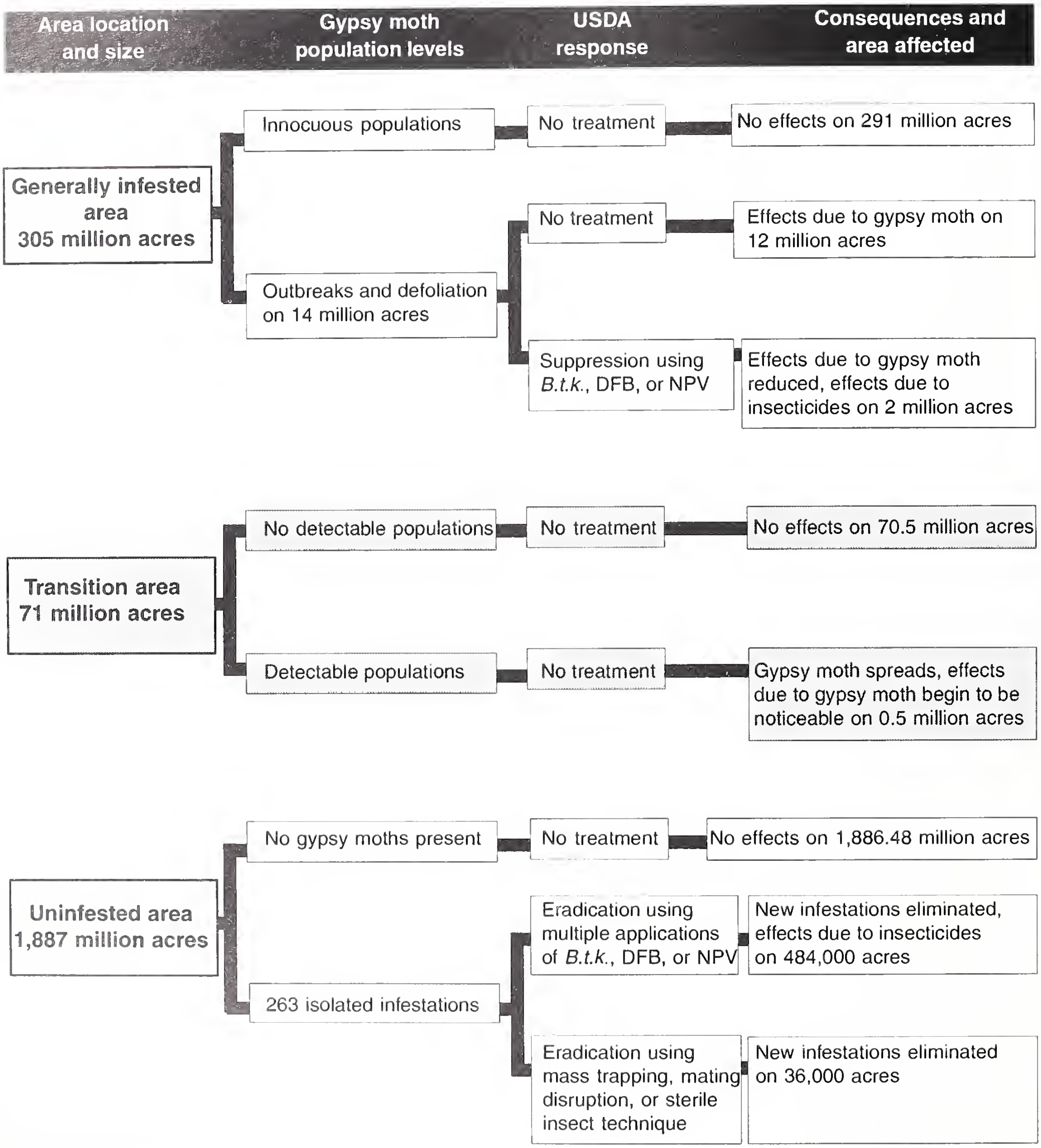


Figure 4-5. Conditions shown for alternative 4 are annual projections in the year 2010.

Consequences of Alternative 5 (eradication and slow the spread)

Area location and size	Gypsy moth population levels	USDA response	Consequences and area affected
Generally infested area 204 million to 271 million acres*	Innocuous populations	No treatment	No effects on 196 million to 259 million acres*
	Outbreaks and defoliation	No treatment	Effects due to gypsy moth on 8 million to 12 million acres*
Transition area 52 million to 63 million acres*	No detectable populations	Survey	No effects on 51.75 million to 62.7 million acres*
	Detectable populations on 250,000 to 300,000 acres*	Slow the spread using *B.t.k.*, DFB, or NPV	Gypsy moth spread is slowed, effects due to gypsy moth delayed, effects due to insecticides on 230,000 to 270,000 acres*
		Slow the spread using mass trapping, mating disruption, or sterile insect technique	Gypsy moth spread is slowed, effects due to gypsy moth delayed on 20,000 to 30,000 acres*
Uninfested area 1,929 million to 2,007 million acres*	No gypsy moths present	No treatment	No effects on 1,928.43 million to 2,006.35 million acres*
	284 to 324 isolated infestations	Eradication using multiple applications of *B.t.k.*, DFB, or NPV	New infestations eliminated, effects due to insecticides on 530,000 to 605,000 acres
		Eradication using mass trapping, mating disruption, or sterile insect technique	New infestations eliminated on 40,000 to 45,000 acres

*** Varies depending on the success of slow the spread strategy**

Figure 4-6. Conditions shown for alternative 5 are annual projections in the year 2010.

Consequences of Alternative 6 (suppression, eradication, and slow the spread)

Area location and size	Gypsy moth population levels	USDA response	Consequences and area affected
Generally infested area 204 million to 271 million acres*	Innocuous populations	No treatment	No effects on 196 million to 259 million acres*
	Outbreaks and defoliation on 8 million to 12 million acres*	No treatment	Effects due to gypsy moth on 7 million to 10 million acres*
		Suppression using *B.t.k.*, DFB, or NPV	Effects due to gypsy moth reduced, effects due to insecticides on 1 million to 2 million acres*
Transition area 52 million to 63 million acres*	No detectable populations	Survey	No effects on 51.75 million to 62.7 million acres*
	Detectable populations on 250,000 to 300,000 acres*	Slow the spread using *B.t.k.*, DFB, or NPV	Gypsy moth spread is slowed, effects due to gypsy moth delayed, effects due to insecticides on 230,000 to 270,000 acres*
		Slow the spread using mass trapping, mating disruption, or sterile insect technique	Gypsy moth spread is slowed, effects due to gypsy moth delayed on 20,000 to 30,000 acres*
Uninfested area 1,929 million to 2,007 million acres*	No gypsy moths present	No treatment	No effects on 1,928.43 million to 2,006.35 million acres*
	284 to 324 isolated infestations	Eradication using multiple applications of *B.t.k.*, DFB, or NPV	New infestations eliminated, effects due to insecticides on 530,000 to 605,000 acres
		Eradication using mass trapping, mating disruption, or sterile insect technique	New infestations eliminated on 40,000 to 45,000 acres

* Varies depending on the success of slow the spread strategy

Figure 4-7. Conditions shown for alternative 6 are annual projections in the year 2010.

Cumulative effects that result from implementing the alternatives can be caused by:

- Repeated gypsy moth outbreaks and defoliation of the same area;
- Multiple treatments of the same project area in the same season;
- Combining treatment types within the same project area; and
- Retreatment of the same project area in the following season, or in a season soon after.

Cumulative effects may be additive or synergistic, that is, the cumulative effect is greater than the sum of the individual effects. Cumulative effects were not quantified at the programmatic level of this environmental impact statement. Estimating cumulative effects is speculative and potentially misleading; however, some general conclusions can be drawn for each alternative.

Cumulative Effects of Alternative 1

Effects due to the gypsy moth would be cumulative under alternative 1 (no suppression, no eradication, no slow the spread), in situations of repeated outbreaks and defoliation of the same area. Repeated defoliation would lead to the changes in forest condition (described in *part B*, under Heavy Defoliation) that are characterized by increased tree mortality, stand structure and composition changes, a shift from production of hard to soft mast, and increased fire danger.

Habitats of wildlife species are altered more with each successive outbreak of the gypsy moth. Recolonization by species lost or displaced due to changes in habitat is possible; however, large areas of defoliation and frequent repeated defoliation do not favor recolonization of species with low dispersal capabilities.

During an outbreak, people may be exposed to gypsy moth caterpillars. Individuals may become sensitized to the gypsy moth after repeated exposures over one or more seasons. Effects include skin and eye irritations, and perhaps aggravated respiratory conditions; however, these do not represent an extreme public health concern.

Shifts are expected in people's perceptions and behaviors with increased exposure to the gypsy moth and multiyear outbreaks.

Economic and recreational consequences that accumulate with repeated multiyear outbreaks include these: costs associated with annual cleanup; maintenance and replacement of trees that die; and loss of value from reduced growth and mortality of trees.

Cumulative Effects of Alternative 2

Effects due to the gypsy moth will be cumulative under alternative 2 (suppression) in situations of repeated outbreaks and defoliation in areas that are not treated. Cumulative effects in these areas will be similar to those described under alternative 1.

Effects of suppression treatments are localized and, on the average, occur on less than 0.6 percent of the generally infested area in any year. Some areas

Large numbers of caterpillars are typical of outbreaks.

may be retreated, and some areas may be close to previously treated areas. Cumulative effects due to insecticide treatments may occur in situations where suppression projects are conducted in the same area in the following season, or in areas close to areas treated in recent years.

Repeated treatments of the same area and, to a lesser degree, treatment of areas close to previously treated areas may result in cumulative effects on nontarget organisms. Susceptible organisms in rare habitats are at greater risk than are organisms with large geographic distributions. Organisms inhabiting specialized habitats may disperse from or into such habitats at low rates or not at all. Organisms that require less specific habitats and have high dispersal rates can recolonize treatment areas. Large treatment areas, frequent retreatment, and low dispersal capabilities of organisms do not favor recolonization.

People also may be exposed to repeated applications of insecticides over several seasons. People may be exposed to diflubenzuron in suppression projects every year for several years; however, available data show that cumulative effects are not likely. For both project workers and people living in suppression project areas, the lifetime cancer risk from exposure to diflubenzuron is less than one in 1 million. Cumulative effects are also unlikely from repeated exposures to *B.t.k.* and Gypchek.

The cost of conducting annual suppression projects would be cumulative.

Cumulative Effects of Alternative 3

Effects due to the gypsy moth would be cumulative under alternative 3 (eradication) in areas where repeated outbreaks and defoliation are not treated. Cumulative effects in these areas would be similar to cumulative effects under alternative 1.

Eradication treatments are localized and conducted on a negligible percentage of the uninfested area in any year. Because eradication typically involves multiple treatments in the same season within the same project area, it may result in cumulative effects.

Repeated treatments of the same area may have cumulative effects on some nontarget organisms. Two or more applications extend the time of potential exposure and risk to a greater number of organisms. As with suppression, the insecticide treatments used in eradication pose greater risk to susceptible organisms in rare habitats than to organisms with large geographic distributions. Eradication project areas are generally smaller than suppression project areas, however, and the opportunity for recolonization would be greater.

Noninsecticidal treatments used in eradication projects pose little risk to nontarget organisms and by themselves do not produce cumulative effects. The risk of cumulative effects is none to minimal from using a noninsecticidal treatment after an insecticide treatment.

Few to no effects on water quality, microclimate, and soil productivity are likely, and the risk of cumulative effects is low.

People may be subject to several exposures through the repeated application of treatments during a single season. After extreme levels of exposure to diflubenzuron, an increase in methemoglobin levels may be detectable in some people. In eradication projects people may be exposed to diflubenzuron twice in a single season; however, cumulative effects are not likely. For both project workers and people living in eradication project areas, the lifetime cancer risk from exposure to diflubenzuron is less than one in 1 million. Repeated exposure of workers to the gypsy moth pheromone is cumulative, resulting in a nuisance from attracting male moths. Other individuals are not likely to be exposed to the gypsy moth pheromone in sufficient quantities to attract male moths.

The cost of conducting annual eradication projects would be cumulative.

Cumulative Effects of Alternative 4

Cumulative effects due to the gypsy moth under alternative 4 (suppression and eradication) would be similar to those described under alternative 1.

Cumulative effects of suppression treatments would be similar to those described under alternative 2, and of eradication treatments would be similar to those described under alternative 3.

Cumulative Effects of Alternative 5

Cumulative effects due to the gypsy moth under alternative 5 (eradication and slow the spread) would be similar to those described under alternative 1.

Cumulative effects due to eradication treatments would be similar to those described under alternative 3. Insecticide treatments used in slow the spread may be applied in the same treatment area in multiple seasons, as in suppression, and might result in cumulative effects similar to those described under alternative 2. In slow-the-spread projects, multiple treatments of *B.t.k.* could be applied in one season and any potential cumulative effects would be similar to those described under alternative 3.

Cumulative effects from using noninsecticidal treatments by themselves or in combination with insecticide treatments are none to minimal.

Cumulative Effects of Alternative 6

Cumulative effects due to the gypsy moth under alternative 6 (suppression, eradication, and slow the spread) would be similar to those described under alternative 1.

Cumulative effects of treatments that may be conducted under this alternative would be similar to those described for suppression treatments under alternative 2, for eradication treatments under alternative 3, and for slow-the-spread treatments under alternative 5. Taken as a whole the potential treatment effects of implementing alternative 6 are greater than any of the other alternatives, since alternative 6 would provide the greatest opportunity for treatment.

Unavoidable Adverse Effects

Despite mitigative measures some adverse environmental effects may occur with all of the alternatives. In many cases what constitutes adverse effects is difficult to determine as they tend to be value judgments. For example, oak trees dying as a result of gypsy moth defoliation and secondary pathogen infection would be an adverse effect to an individual intending to market the trees as timber. Death of those same trees after defoliation may be viewed by others as beneficial by providing more diverse and improved habitat for some wildlife species.

Unavoidable adverse environmental effects may occur at the site-specific level. These effects would vary with the type of treatment, how it is used, the size of the treatment area, and site-specific environmental factors. Here are examples:

- Use of insecticides that are not gypsy-moth-specific (*B.t.k.* and diflubenzuron) would affect some nontarget organisms.
- If exposed to the direct spray of *B.t.k*, diflubenzuron, or Gypchek, some people may have minor irritation of the skin, eyes, or respiratory tract.
- Irritations of the skin, eyes, and respiratory tract would be more likely in workers with repeated exposure to *B.t.k*, diflubenzuron, or Gypchek than in the general public.

Alternative 6 would provide the greatest opportunity for treatment.

- Exposure to gypsy moth caterpillars could cause temporary irritation of the skin, eyes, or respiratory tract in some individuals.
- The physical aspects of aerial application, such as noise and low flying aircraft, may disturb people and some animals. Conducting projects poses risks that include insecticide spills, aircraft and automobile accidents, and other hazards to project workers, such as attacks by dogs and stinging insects.
- Some people would experience stress or anxiety associated with gypsy moth outbreaks and would want agencies to control the insect. At the same time in the same area, some people would experience stress or anxiety associated with treatments and would voice opposition to treatment.
- Environmental consequences would result from the gypsy moth in areas that are not treated.

Short-Term Uses Versus Long-Term Productivity

Short-term uses are those activities that generally occur on a yearly basis with anticipated resource outputs or conditions. Long-term productivity is the capability of an area to provide resources into the future. All of the alternatives in this environmental impact statement would have both short- and long-term implications.

The presence of the gypsy moth, defoliation, and the use of treatments have ecological, social, and economic effects that appear soon after defoliation or after the treatments are applied. Whether the presence of the gypsy moth affects long-term productivity is determined by the gypsy moth population level, the degree of defoliation, and the duration of the outbreak. The original condition or vulnerability of the resources, particularly host vegetation, is also a factor. Repeated heavy defoliation causes greater change to long-term productivity of resources and outputs than does moderate defoliation in only 1 or 2 years. Whether alternatives with treatments result in change to long-term productivity is determined by the treatments used, the extent to which they are used, whether treatments are repeated in one year or in consecutive years, and the original condition or vulnerability of the resources.

Gypsy Moth

Damage caused by gypsy moth caterpillars can have a negative effect on recreational use and backyard activities in spring and early summer. Recreational use patterns may shift to undefoliated areas for the remainder of the recreation season; however, use patterns vary within a season and are not known to be permanently affected by the gypsy moth.

In situations where the gypsy moth becomes established and causes damage to forest and shade trees, value may be lost. Undeveloped forests with commercial value may have short-term losses in timber volume and value from mortality. These may be offset, however, by long-term growth of residual trees (Gansner and others 1983). Surviving trees would benefit from the reduced number of trees and less competition for sunlight, water, and nutrients. Long-term productivity of these forests may be increased by repeated defoliation that results in stands that are less susceptible to future gypsy moth outbreaks. Numbers of tree species would increase (Quimby 1993).

Trees in developed areas may have short-term losses in growth and value as shade trees and ornamentals. Repeated defoliation may lead to mortality and, in some cases, added costs for replacement. Long-term benefits do not offset these losses and costs, as can be the case in undeveloped forests.

Defoliation in general disrupts wildlife communities in the short term. In the long term, a greater variety of wildlife may result from defoliation caused by the gypsy moth (DeGraff and others 1992, Tomblin 1994).

Treatments

Recreational use of areas sprayed with insecticides could diminish during spray operations, then resume once spraying has been completed. Spraying is usually conducted in the morning,

occasionally in the afternoon and early evening when weather conditions are favorable, and may take from one to several days to complete. Reduction in recreation use could be extended by eradication, which may require multiple treatments in the same season.

The more successful insecticidal treatments are in reducing defoliation caused by the gypsy moth, the shorter is the interruption in use of the area due to the presence of the gypsy moth or defoliation. Noninsecticidal treatments also delay or minimize the possibility of effects from the gypsy moth, lessening the potential for short-term effects on recreation.

Long-term forest productivity is not known to be adversely affected by either insecticides or noninsecticidal treatments, and is enhanced by a reduction in effects due to the gypsy moth.

Irreversible and Irretrievable Commitment of Resources

Irreversible and irretrievable commitments of resources could occur at the project level due to the presence of the gypsy moth and defoliation or treatments. These irreversible and irretrievable commitments of resources need to be disclosed through site-specific analysis.

Irreversible Commitment of Resources

An irreversible commitment of resources results in the permanent loss of nonrenewable resources, such as minerals or cultural resources; resources that are renewable only over long periods of time, such as soil productivity; or extinction of a species. In all but alternative 1, the labor and fossil fuel used and money spent in gypsy moth treatment projects represent an irreversible commitment of resources.

Alternatives 1 and 2 will not prevent establishment of the gypsy moth in the uninfested area. Historic eradication efforts in the 20th century have shown that once gypsy moth populations are established, eradication is not possible. Therefore, the spread and establishment of the gypsy moth and the loss of uninfested areas is irreversible.

In alternatives 1, 2, 3, and 5, which do not include both suppression and eradication, wilderness and other special areas where undisturbed vegetation is part of the area's value may be changed due to defoliation by the gypsy moth. Loss of undisturbed vegetation and other dependent natural resources in such areas would be irreversible.

Irretrievable Commitment of Resources

An irretrievable commitment is one in which a resource product or use is lost for a period of time while managing for another. The loss is irretrievable, but the use of the area is not irreversible. Alternatives 1, 3, and 5, which do not include suppression, may result in the loss of production or use of natural resources, such as for timber or recreation, as a result of defoliation and subsequent tree mortality.

Plans and Programs of Others

Federal agencies are directed to cooperate to the extent possible to reduce duplication and avoid conflict with State laws, plans of other Federal agencies, and State and local plans (40 CFR 1506.2(c)).

The decision resulting from the analysis contained in this environmental impact statement directly affects how and to what degree the USDA would cooperate with and assist other Federal agencies and States in managing gypsy moth populations. Private landowners and land managers requesting assistance would work through appropriate State agencies.

Under all alternatives, any Federal agency or authorized State agency could request USDA assistance in gypsy moth management activities. The difference between alternatives is how the Forest

Service and APHIS would respond to the request. These differences are explained below. Under all alternatives the USDA would be available on request for technical assistance, such as conducting surveys and evaluations, planning public involvement activities, and assisting in project planning.

No Suppression, No Eradication, No Slow the Spread

Under alternative 1 the decision to eradicate, suppress, or slow the spread of the gypsy moth would rest with other Federal agencies and States. They would also be responsible for public notification and involvement and any environmental documentation that is needed. Without USDA participation, the number of gypsy moth treatment projects and the total area treated annually probably would be reduced.

Suppression

Under alternatives 2, 4, and 6, the USDA could assist other Federal agencies and States in planning and conducting gypsy moth suppression projects.

No Suppression

Under alternatives 1, 3, and 5, the decision to suppress gypsy moth outbreaks would rest with other Federal agencies and States. They would also be responsible for public notification and involvement and any environmental documentation that is needed. Without USDA participation, the number of acres treated annually to reduce damaging effects caused by the gypsy moth probably would be reduced.

Eradication

Under alternatives 3, 4, 5, and 6, the USDA could assist other Federal agencies and States in planning and conducting eradication projects. Detection surveys conducted jointly by APHIS and cooperators would continue. Delimiting surveys using pheromone traps and larval surveys would determine the extent of isolated infestations.


Coordination of gypsy moth management activities requires cooperation.

No Eradication

Under alternatives 1 and 2, the decision to eradicate isolated gypsy moth infestations would rest with other Federal agencies and States. They would also be responsible for public notification and involvement and any environmental documentation that is needed. Without USDA participation the number of eradication projects conducted annually probably would decline. Newly infested areas will most likely be placed under gypsy moth quarantine by the USDA.

Slow the Spread

Under alternatives 5 and 6, other Federal agencies and States could cooperate with the USDA in implementing activities that support the slow-the-spread strategy. Surveys, monitoring, posttreatment evaluations, and other support activities could be conducted jointly by the USDA and cooperators in and near the transition area.

No Slow the Spread

Under alternatives 1, 2, 3, and 4, it is unlikely that other Federal agencies or States would slow the spread of the gypsy moth. In the event they did, they would also be responsible for public notification and involvement and any environmental documentation that is needed.

Other

Other Federal agencies and States that wish to participate in the national gypsy moth management program would follow their agency's statutory authorities, procedures, and policies for cooperating with the USDA.

The gypsy moth is a management concern in areas along the border between Canada and the United States. Actions taken in the United States could influence Canadian policies, commerce, and tourism. Gypsy moth conditions in the United States along the Canadian border may influence the actions taken by the Canadian Forest Service, Agriculture Canada, and Agri-Food Canada. For example, a national gypsy moth management program that does not include eradication could result in establishment of new populations that would be close to and threaten the uninfested area in Canada. A program that does not include suppression could threaten gypsy moth-free areas of Canada and possibly affect trade with the United States.

Chapter 5

Preparers

Pruning and scraping trees, circa 1894

Chapter 5
Preparers
Contents

Interdisciplinary Team

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Supervisory forester and environmental impact statement (EIS) team leader, USDA Forest Service, Northeastern Area State and Private Forestry, Radnor, PA.

Twenty years with the Forest Service in positions involving forest administration, forest planning, wild and scenic rivers, timber management, logging systems, silviculture, ecosystem management, and other forest resources. Worked on these environmental impact statements: Appalachian Integrated Pest Management Gypsy Moth Demonstration EIS, Monongahela National Forest Plan EIS, Bluestone Wild and Scenic River EIS, Gauley Wild and Scenic River EIS, and Greenbrier Wild and Scenic River EIS (team leader). Held forestry and recreation related positions with the State of Delaware and private forest industries in West Virginia and Virginia. Received a B.S.F. in forestry from West Virginia University in 1971.

Gary M. Peters

Biologist and NEPA specialist, USDA Forest Service, Northeastern Area State and Private Forestry, Radnor, PA.

Eighteen years with the Forest Service in positions responsible for wildlife and fish, endangered and threatened species, special areas, timber management, land management planning, cultural resources, pesticides, and social impact analysis. Worked on these environmental impact statements: Francis Marion National Forest Land Management Plan Revision, Hoosier National Forest Land Management Plan Amendment, Appalachian Integrated Pest Management Gypsy Moth Demonstration EIS, Wayne National Forest Land Management Plan, and Hoosier National Forest Land Management Plan. Received an A.A.S. in wildlife management from Hocking Technical College, Nelsonville, OH, in 1975, and a B.S. in Public Affairs and Environmental Science from Indiana University in 1983.

Noel F. Schneeberger

Entomologist, USDA Forest Service, Northeastern Area State and Private Forestry, Radnor, PA.

Sixteen years with the Forest Service in Forest Health Protection, working with State and Federal agencies to plan, develop, implement, and evaluate gypsy moth and other forest pest management programs on Federal, State, and private lands. Worked on the 1985 EIS on Gypsy Moth Suppression and Eradication Projects, and on several environmental impact statements prior to that. Worked 2 years as the forest pest specialist with the South Dakota Division of Forestry in Rapid City. Received a B.S. in biology from Wittenberg University, Springfield, OH, in 1974, and an M.S. in forest entomology from Duke University in 1976.

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Sixteen years with the Forest Service. Worked 8 years as technical publications editor and 5 years as editorial assistant. Three years with the U.S. Department of the Army preparing administrative correspondence and regulations. Received a B.A. in biology from Montclair State College, NJ, in 1975.

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Twenty-five years with APHIS in positions involving policy analysis and development, program planning and development, field operations support, port operations, plant protection and quarantine, and training and professional development. Received a B.S. in wildlife biology from Purdue University in 1969.

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Forester, USDA Forest Service, Northeastern Area State and Private Forestry, Radnor, PA.

Nineteen years with the Forest Service, reviewing environmental documents to assure compliance with laws and policy, providing guidance on analysis and documentation of environmental decisions, and working as a forest entomologist. Four years as an international expert with the United Nations' World Health Organization, African Region. Four years as program coordinator with the U.S. Environmental Protection Agency. Received a B.S. in entomology from the University of Delaware in 1960.

Gerald W. Williams

Regional sociologist and social historian, USDA Forest Service, Pacific Northwest Region, Portland, OR, and adjunct staff member at Grey Towers National Historic Landmark, Milford, PA.

Fifteen years with the Forest Service, working in social and social impact analysis at all levels of the agency. Worked on several Forest Service and interagency environmental impact statements, including the Clinton Forest Plan, the Supplemental EIS on Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl, Pacific Yew EIS, Pacific Northwest Region

Vegetation Management EIS, and long-range interdisciplinary plans for the Umpqua and Williamette National Forests. Taught for 2 years at Indiana State University. Worked 1 year as recreation research director for the city of Eugene, OR. Has authored several books covering aspects of the past, present, and trends into the future. Received a B.S. in sociology (1971) and an M.S. in general studies social science (1972) from Southern Oregon State College, and a Ph.D. in sociology from Washington State University in 1976.

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Twenty years in Federal service with the Environmental Protection Agency, Bureau of Land Management, Fish and Wildlife Service, and Animal and Plant Health Inspection Service, working on a wide range of environmental issues. Received a B.S. in biology from Grove City College in 1971, and an M.S. in biology from West Virginia University in 1974.

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Fifteen years in aquatic and systems ecology and modeling with two universities, private industry, and Federal service—the U.S. Environmental Protection Agency, and USDA Animal and Plant Health Inspection Service. Received a B.S. in biology from Florida Southern College in 1977, an M.S. in environmental biology from George Mason University in 1981, and a Ph.D. in biology-ecology from Utah State University in 1990.

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Fourteen years experience in toxicology, public health, worker safety, pesticide usage, and entomology, with private organizations and local and Federal governments. Received a B.S. in environmental science in 1978, an M.S. in entomology from Purdue University in 1981, and an M.P.H. in disease control (1984) and a Ph.D. in toxicology (1988) from the University of Texas.

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Chapter 6

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Putting on burlap bands, circa 1891

Chapter 6
Consultants and Contributors

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Chapter 7

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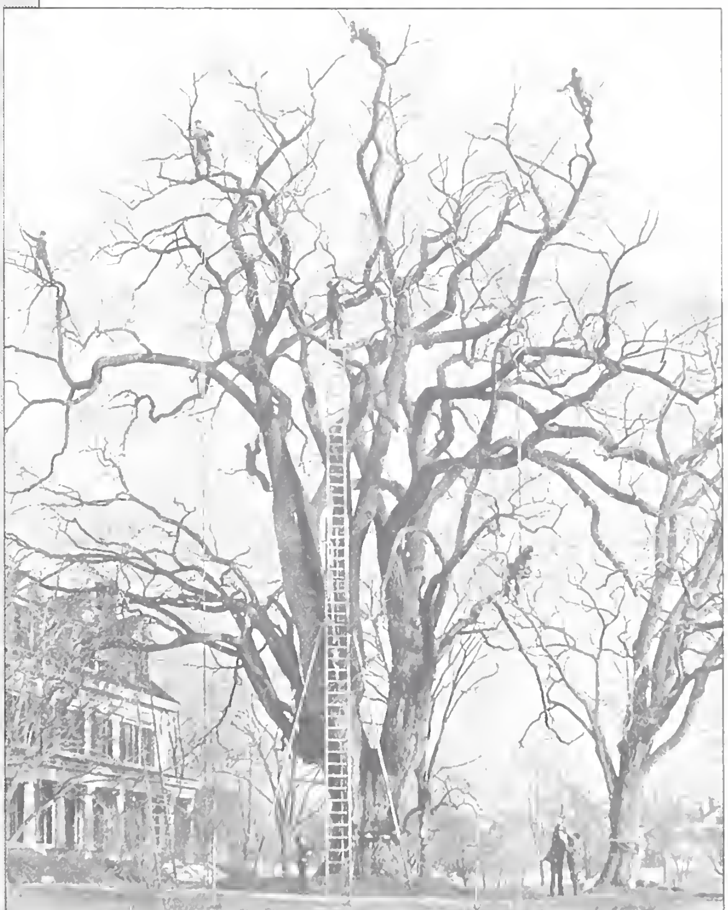

The Dexter Elm, Malden, Massachusetts, circa 1891

Chapter 7
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This chapter lists agencies, organizations, libraries, and individuals who were sent complete copies of this final environmental impact statement.

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Committee on Agriculture, Nutrition and Forestry

Honorable Frank Murkowski, *chairman*
Committee on Energy and Natural Resources

Honorable J. Bennett Johnston, *ranking minority member*
Committee on Energy and Natural Resources

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Honorable Pat Roberts, *chairman*
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Honorable Kika de la Garza, *ranking minority member*
Committee on Agriculture

Honorable Don Young, *chairman*
Committee on Resources

Honorable George Miller, *ranking minority member*
Committee on Resources

Federal Agencies

Alabama
- **DOD,** *U.S. Army Missile Command*
- **USDA, Animal and Plant Health Inspection Service,** *Plant Protection and Quarantine*
- **USDA, Forest Service,** *National Forests in Alabama*
- **USDA, Rural Economic and Community Development Services**

Alaska
- **U.S. Department of Commerce,** *National Marine Fisheries Service*
- **USDA, Animal and Plant Health Inspection Service,** *Plant Protection and Quarantine*
- **USDA, Forest Service,** *Alaska Region*
- **USDA, Rural Economic and Community Development Services**
- **USDI, Fish and Wildlife Service**
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Mailing List

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- **Advisory Council on Historic Preservation,** *Office of Program Review and Education*
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- **Federal Railroad Administration,** *Office of Policy*
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- **Office of Economic Opportunity,** *Equal Employment Opportunity Commission*
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- **U.S. Department of Housing and Urban Development,** *Office of Environment and Energy*
- **U.S. Department of Transportation,** *Environmental Division*
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DOD, U.S. Army Corps of Engineers, *South Atlantic Division*
Environmental Protection Agency, *Environmental Policy Section, Region IV*
Environmental Protection Agency, Federal Activities Branch, *Environmental Policy Section*
Federal Aviation Administration, *Southern Region*
Federal Highway Administration, *Region 4*
Federal Highway Administration, *Regional Administrator*
U.S. Department of Health and Human Services, *Centers for Disease Control*
U.S. Department of Housing and Urban Development
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *Chattahoochee and Oconee National Forests*
USDA, Forest Service, *Southern Region*
USDA, *Office of the General Counsel*
USDA, Rural Economic and Community Development Services
USDI, Fish and Wildlife Service
USDI, National Park Service, *Southeast Regional Office*

Hawaii
DOD, U.S. Army Corps of Engineers, *Pacific Ocean Division*
DOD, *U.S. Army Engineer District*
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Rural Economic and Community Development Services

Idaho
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Rural Economic and Community Development Services

Illinois
DOD, Navy, *Naval Training Center*
DOD, U.S. Army Corps of Engineers, *North Central Division*
DOD, U.S. Army Corps of Engineers, *Rock Island District*
Environmental Protection Agency, *Region V*
Federal Aviation Administration, *Great Lakes Region*
Federal Highway Administration, *Region 5*
U.S. Department of Housing and Urban Development
USA CERL
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *Shawnee National Forest*
USDA, Rural Economic and Community Development Services
USDI, Fish and Wildlife Service, *Cypress Creek National Wildlife Refuge*

Indiana
DOD, Navy
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *Hoosier National Forest*
USDA, Rural Economic and Community Development Services
USDI, National Park Service

Iowa

USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*

USDA, Rural Economic and Community Development Services

Kansas

Environmental Protection Agency, *Region VII*

U.S. Department of Housing and Urban Development

USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*

USDA, Rural Economic and Community Development Services

Kentucky

Ohio River Basins Commission

USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*

USDA, Forest Service, *Daniel Boone National Forest*

USDA, Rural Economic and Community Development Services

Louisiana

USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*

USDA, Forest Service, *Kisatchie National Forest*

USDA, Forest Service, *Southern Forest Experiment Station*

USDA, Rural Economic and Community Development Services

Maine

USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*

USDA, Rural Economic and Community Development Services

Maryland

DOD, Army, *Aberdeen Proving Ground*

DOD, Army, *Fort Meade, Entomology Section*

DOD, Navy, *Naval Surface Warfare Center*

Federal Highway Administration, *Region 3*

USDA, Animal and Plant Health Inspection Service, *Biologics, Biotechnology, and Enviromental Protection, Environmental Analysis and Documentation*

USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*

USDA, National Agriculture Library

USDA, Natural Resources Conservation Service, *Garrett County Office*

USDI, Fish and Wildlife Service, *Blackwater National Wildlife Refuge*

USDI, Fish and Wildlife Service, *Chesapeake Bay Field Office*

USDI, Fish and Wildlife Service, *Eastern Neck National Wildlife Refuge*

USDI, Fish and Wildlife Service, *Patuxent Wildlife Research Center*

USDI, National Park Service

USDI, National Park Service, *C & O Canal National Historic Park*

USDI, National Park Service, *Catoctin Mountain Park*

USDI, National Park Service, *Greenbelt Park*

Massachusetts

DOD, U.S. Army Corps of Engineers, *New England Division*

Environmental Protection Agency, *Region I*

Federal Aviation Administration, *New England Region*

U.S. Department of Commerce, *National Marine Fisheries Service*

U.S. Department of Housing and Urban Development

USDA, Animal and Plant Health Inspection Service, *Otis Plant Methods Center*

USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*

USDA, Rural Economic and Community Development Services

USDI, Fish and Wildlife Service

USDI, National Park Service, *Cape Cod National Seashore*

Michigan

DOD, Air Force, *KI Sawyer Air Force Base*

Michigan National Guard Headquarters

USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*

USDA, Forest Service, *Hiawatha National Forest*

USDA, Forest Service, *Huron-Manistee National Forest*

USDA, Forest Service, *Ottawa National Forest*

USDA, *Niles Biological Control Laboratory*

USDA, Rural Economic and Community Development Services

USDI, National Park Service, *Sleeping Bear Dunes National Lakeshore*

Minnesota

USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *Chippewa National Forest*
USDA, Forest Service, *North Central Forest Experiment Station*
USDA, Forest Service, *Superior National Forest*
USDA, Rural Economic and Community Development Services
USDI, Fish and Wildlife Service
USDI, National Park Service, *North Central Regional Office*
USDI, National Park Service, *Voyageurs National Park*

Mississippi

DOD, U.S. Army Corps of Engineers, *Lower Mississippi Valley Division*
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *National Forests in Mississippi*
USDA, Rural Economic and Community Development Services

Missouri

DOD, Air Force, *Whiteman Air Force Base*
Environmental Protection Agency, *Environmental Review and Coordination Section, Region VII*
Federal Aviation Administration, *Central Region*
Federal Highway Administration, *Region 7*
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *Mark Twain National Forest*
USDA, Rural Economic and Community Development Services
USDI, National Park Service, *Ozark National Scenic Riverways*
USDI, National Park Service, *Wilson's Creek National Battlefield*

Montana

USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *Northern Region*
USDA, Rural Economic and Community Development Services
USDI, Bureau of Land Management, *Montana State Office*
USDI, Fish and Wildlife Service, *Bowdoin National Wildlife Refuge*
USDI, National Park Service, *Glacier National Park*

Nebraska

DOD, U.S. Army Corps of Engineers, *Missouri River Division*
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Rural Economic and Community Development Services
USDI, National Park Service

Nevada

USDA, Rural Economic and Community Development Services

New Hampshire

USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *Northeastern Area and Northeastern Forest Experiment Station*
USDA, Forest Service, *White Mountain National Forest*
USDI, Fish and Wildlife Service, *New England Field Office*

New Jersey

Delaware River Basin Commission
DOD, Army, *U.S. Army Armament Research*
DOD, Earle Naval Weapons Depot
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Rural Economic and Community Development Services
USDI, Fish and Wildlife Service, *Edwin B. Forsythe National Wildlife Refuge*
USDI, Fish and Wildlife Service, *New Jersey Field Office*

New Mexico

USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *Southwestern Region*
USDA, Rural Economic and Community Development Services
USDI, National Park Service, *Southwest Regional Office*

New York
- **DOD, Army, U.S. Military Academy**
- **DOD, U.S. Army Corps of Engineers,** *North Atlantic Division*
- **Environmental Protection Agency,** *Environmental Impacts Branch, Region II*
- **Federal Aviation Administration,** *Eastern Region*
- **Federal Highway Administration,** *Region 1*
- **U.S. Department of Housing and Urban Development**
- **USDA, Animal and Plant Health Inspection Service,** *Plant Protection and Quarantine*
- **USDA, Rural Economic and Community Development Services**
- **USDI, National Park Service,** *Fire Island National Seashore, William Floyd Estate*

North Carolina
- **DOD, U.S. Army Corps of Engineers,** *Wilmington District*
- **North Carolina National Guard,** *Adjutant General*
- **USDA, Animal and Plant Health Inspection Service,** *Plant Protection and Quarantine*
- **USDA, Forest Service,** *National Forests in North Carolina*
- **USDA, Rural Economic and Community Development Services**
- **USDI, Fish and Wildlife Service**
- **USDI, National Park Service,** *Blue Ridge Parkway*

North Dakota
- **USDA, Animal and Plant Health Inspection Service,** *Plant Protection and Quarantine*
- **USDA, Rural Economic and Community Development Services**

Ohio
- **DOD, Army,** *Ravenna Army Ammunition Plt.*
- **DOD, U.S. Air Force Reserves**
- **DOD, U.S. Army Corps of Engineers,** *Caesar Creek Lake*
- **DOD, U.S. Army Corps of Engineers,** *Clarence J. Brown Dam*
- **DOD, U.S. Army Corps of Engineers,** *Ohio River Division*
- **DOD, U.S. Army Corps of Engineers,** *West Fork Lake*
- **DOD, U.S. Army Corps of Engineers,** *William H. Harsha Lake*
- **USDA, Animal and Plant Health Inspection Service,** *Plant Protection and Quarantine*
- **USDA, Forest Service,** *Wayne National Forest*
- **USDA, Rural Economic and Community Development Services**
- **USDI, National Park Service**

Oklahoma
- **USDA, Animal and Plant Health Inspection Service,** *Plant Protection and Quarantine*
- **USDA, Rural Economic and Community Development Services**

Oregon
- **DOD, U.S. Army Corps of Engineers,** *North Pacific Division*
- **Federal Highway Administration,** *Region 10*
- **Northwest Power Planning Council**
- **U.S. Department of Commerce,** *National Marine Fisheries Service*
- **U.S. Department of Energy,** *Bonneville Power Administration*
- **USDA, Animal and Plant Health Inspection Service,** *Plant Protection and Quarantine*
- **USDA, Forest Service,** *Pacific Northwest Region*
- **USDA, Forest Service,** *Pacific Northwest Research Station*
- **USDA, Rural Economic and Community Development Services**
- **USDI, National Park Service,** *Eastside Federal Complex*

Pennsylvania
- **DOD, Army,** *Fort Indiantown Gap Military Reservation*
- **DOD, Letterkenny Army Depot**
- **DOD, U.S. Army Corps of Engineers**
- **DOD, U.S. Army Corps of Engineers,** *Blue Marsh Lake*
- **DOD, U.S. Army Corps of Engineers,** *Crooked Creek Lake*
- **DOD, U.S. Army Corps of Engineers,** *Curwensville Lake*
- **DOD, U.S. Army Corps of Engineers,** *East Branch Clarion River Lake*
- **DOD, U.S. Army Corps of Engineers,** *Kinzua Dam and Allegheny Reservoir*
- **DOD, U.S. Army Corps of Engineers,** *Raystown Lake*
- **DOD, U.S. Army Corps of Engineers,** *Shenango Lake*
- **DOD, U.S. Army Corps of Engineers,** *Youghiogheny Lake*

Environmental Protection Agency, *Environmental Services Division*
Environmental Protection Agency, *Region III*
Susquehanna River Basins Commission
U.S. Department of Housing and Urban Development
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *Allegheny National Forest*
USDA, Forest Service, *Northeastern Area State and Private Forestry*
USDA, Forest Service, *Northeastern Forest Experiment Station*
USDA, Rural Economic and Community Development Services
USDI, *Delaware Water Gap National Recreation Area*
USDI, Fish and Wildlife Service, *John Heinz National Wildlife Refuge at Tinicum*
USDI, Fish and Wildlife Service, *Pennsylvania Field Office*
USDI, National Park Service
USDI, National Park Service, *Friendship Hill National Historic Park*
USDI, National Park Service, *U.S. Customs House*
USDI, National Park Service, *Valley Forge National Historical Park*

Rhode Island
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Natural Resources Conservation Service

South Carolina
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *Francis Marion and Sumter National Forests*
USDA, Rural Economic and Community Development Services

South Dakota
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Rural Economic and Community Development Services

Tennessee
Tennessee Valley Authority, *Environmental Quality*
Tennessee Valley Authority, *NEPA Administration*
Tennessee Valley Authority, *Transportation Planning and Protection Branch*
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *Cherokee National Forest*
USDA, Rural Economic and Community Development Services
USDI, National Park Service, *Great Smoky Mountains National Park*

Texas
DOD, U.S. Army Corps of Engineers, *Southwestern Division*
Environmental Protection Agency, *Region VI*
Federal Aviation Administration, *Southwest Region*
Federal Highway Administration, *Region 6*
U.S. Department of Housing and Urban Development
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *National Forests in Texas*
USDA, Rural Economic and Community Development Services

Utah
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *Intermountain Region*
USDA, Forest Service, *Intermountain Research Station*
USDA, Rural Economic and Community Development Services

Vermont
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *Green Mountain and Finger Lakes National Forests*
USDA, Rural Economic and Community Development Services

Virginia
Deputy Assistant Secretary of Defense
DOD, Air Force, *Langley Air Force Base*
DOD, Army, *Arlington National Cemetery*
DOD, Army, *Fort A.P. Hill*
DOD, Army, *Fort Belvoir*
DOD, Army, *Fort Eustis*
DOD, Army, *Fort Myer*

Environmental Protection Agency, *Reg. Div. H7505C*
MCCDC, NREA - *Forestry*
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *George Washington National Forest*
USDA, Forest Service, *Jefferson National Forest*
USDA, Rural Economic and Community Development Services
USDI, Bureau of Land Management
USDI, Fish and Wildlife Service, *Virginia Field Office*
USDI, National Park Service, *Fredericksburg and Spotsylvania National Military Park*
USDI, National Park Service, *Prince William Forest Park*
USDI, National Park Service, *Shenandoah National Park*
USDI, National Park Service, *Richmond National Battlefield Park*
Virginia Cooperative Extension, *Loudoun Office*

Washington
Environmental Protection Agency, *Region X*
Federal Aviation Administration, *Northwest Region*
Resource Protection, *Department of Natural Resources*
U.S. Department of Energy, *Richland Operations*
U.S. Department of Housing and Urban Development
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Rural Economic and Community Development Services

West Virginia
DOD, U.S. Army Corps of Engineers, *Bluestou Lake*
DOD, U.S. Army Corps of Engineers, *OR-R*
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Forest Service, *Monongahela National Forest*
USDA, Forest Service, *Northeastern Area and Northeastern Forest Experiment Station*
USDA, Natural Resources Conservation Service, *Tucker County*

USDA, Rural Economic and Community Development Services
USDI, National Biological Service

Wisconsin
DOD, Army, *Commanding Officer*
DOD, U.S. Army Corps of Engineers, *Eau Galle Lake*
USDA, , *Plant Protection and Quarantine*
USDA, Forest Service, *Chequamegon National Forest*
USDA, Forest Service, *Eastern Region*
USDA, Forest Service, *Nicolet National Forest*
USDA, *Office of the General Counsel*
USDA, Rural Economic and Community Development Services
USDI, Fish and Wildlife Service, *Trempealeah National Wildlife Refuge*

Wyoming
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Rural Economic and Community Development Services
USDI, National Park Service

Guam
Department of Agriculture, *Forestry and Soil Resources Division*

Puerto Rico
USDA, Animal and Plant Health Inspection Service, *Plant Protection and Quarantine*
USDA, Rural Economic and Community Development Services

State and Local Agencies

Alabama
Alabama Department of Agriculture, *Plant Industry Section*
Alabama Forestry Commission

Alaska
Alaska Department of Natural Resources

Arizona
Arizona Game and Fish Department, *Habitat Branch Chief*

Arkansas

Arkansas Development Finance Authority
Arkansas Forestry Commission
Arkansas Game and Fish Commission
Arkansas State Highway and Transportation, *Facilities Management*
Arkansas State Plant Board
Farm Bureau
Newton County Wildlife Association
Southwest Arkansas RC&D
University of Arkansas, *Agriculture Experiment Station*

California

California Department of Food and Agriculture
California Department of Forestry and Fire Protection
Siskiyou County Agriculture Department
Sutter County Department of Agriculture
Watsonville County Commissioner's Office

Colorado

Colorado State University Cooperative Extension, *Adams County*
IPM Coordinator

Connecticut

Connecticut Agricultural Experiment Station
Department of Environmental Protection, *State Forester*
Regional Water Authority
State Forestry and Fire, *Connecticut Valley Headquarters*
State of Connecticut, *Department of Health Services*
University of Connecticut Extension System

Delaware

Delaware Division of Parks and Recreation
Delaware State University, Department of Agriculture and Natural Resources
Department of Agriculture and Natural Resources
Department of Agriculture, *State Forester*
Department of Natural Resources and Environmental Control

Florida

Florida Department of Agriculture and Consumer Services
Florida Department of Agriculture, *Division of Plant Industry*
Florida Department of Environmental Protection
Florida Division of Forestry, *Forest Health Section*
Florida Division of Parks and Recreation

Georgia

Georgia Forestry Commission

Idaho

Idaho Department of Lands, *Insect and Disease Section*

Illinois

Chicago Park District
Cooperative Extension Service *Clark County*
Cooperative Extension Service *Edwards County*
Cooperative Extension Service *Region 6*
Cooperative Extension Service *Region 7*
Cooperative Extension Service *Tazewell County*
Cooperative Extension Service *Warren - Henderson Ext. Unit*
Department of Conservation, *State Forester*
Illinois Department of Agriculture
Illinois Department of Public Health, *Division of Environmental Health*
Marion Extension Center
Shawnee RC&D Area
Two Rivers RC&D Area

Indiana

Cooperative Extension Service *Cass County*
Cooperative Extension Service *Dekalb County*
Cooperative Extension Service *Elkhart County*
Cooperative Extension Service *Harrison County*
Cooperative Extension Service *Huntington County*
Cooperative Extension Service *Shelby County*
Cooperative Extension Service *Washington County*
Indiana Department of Natural Resources, *Division of Entomology and Plant Pathology*
Indiana Department of Natural Resources, *State Forester*
Lincoln Hills RC&D Area
Purdue University
State Board of Health
Villonia State Tree Nursery

Iowa

Cooperative Extension Service *Adams County*
Cooperative Extension Service *Audubon County*
Cooperative Extension Service *Butler County*
Cooperative Extension Service *Cerro Gordo County*

Cooperative Extension Service *Des Moines County*
Cooperative Extension Service *Fremont County*
Cooperative Extension Service *Jasper County*
Cooperative Extension Service *Palo Alto County*
Cooperative Extension Service *Shelby County*
Cooperative Extension Service *West Pottawattamie County*
Iowa Department of Agriculture
Iowa Department of Agriculture, *Entomology and Seed Bureau*
Iowa Department of Natural Resources, *State Forester*
Loess Hills State Forest
Stephens State Forest

Kansas

Kansas State Board of Agriculture, *Plant Protection and Weed Control*

Kentucky

Kentucky Department of Environmental Protection
Kentucky Department of Fish and Wildlife Resources
Kentucky Department of Natural Resources
Kentucky Division of Forestry

Louisiana

Capital RC&D
Louisiana Department of Agriculture and Forestry
Louisiana State University Cooperative Extension Service

Maine

Board of Pesticides Control
Maine Department of Conservation, Maine Forest Service, *State Forester*
Maine Forest Service, *Insect and Disease Management Division*

Maryland

Bureau of Parks, *Forestry Division*
Cooperative Extension Service *Carroll County*
Cooperative Extension Service *Comm. Horticulture*
Cooperative Extension Service *Howard County*
Cooperative Extension Service *Wicomico County*
Cooperative Extension Service *Worcester County*
Environmental Management Office
Garrett County ASCS Office
Greater Severna Park Council
Maryland Department of Agriculture, *Forest Pest Management*
Maryland Department of Agriculture, *Gypsy Moth Field Office*
Maryland Department of Agriculture, *Pesticide Regulation Section*
Maryland Forest, Park and Wildlife Service
Maryland National Capital Parks and Planning Commission
Montgomery County Conservation Corps
Natural Resources Department, Public Lands and Forestry, *State Forester*
Recreation and Parks
University of Maryland Cooperative Extension Service

Massachusetts

Berkshire-Pioneer RC&D Area
Cooperative Extension System
Department of Environmental Management, *Division of Forests and Parks*
Department of Food and Agriculture, *Bureau of Plant Industry*
Massachusetts Department of Environmental Management, *Commissioner*
Massachusetts Department of Environmental Management, *Chief Forester*
Massachusetts Division of Forests and Parks
Western Massachusetts Agriculture Center

Michigan

Alcona County Gypsy Moth Suppression Program
Arenac County Gypsy Moth Suppression Program
Bay County Gypsy Moth Suppression Program
Benzie/Grand Traverse/Leelanau Gypsy Moth Suppression Program
Benzie/Manistee Soil Survey Manistee County
Clare County Gypsy Moth Program
Cooperative Extension Service *Barry County*
Cooperative Extension Service *Benzie County*
Cooperative Extension Service *Cheboygan County*
Cooperative Extension Service *Clinton County*
Cooperative Extension Service *Gladwin County*
Cooperative Extension Service *Iosco County*
Cooperative Extension Service *Presque Isle*
Cooperative Extension Service *St. Clair County*
Cooperative Extension Service *Tuscola County*
Department of Forestry and Wildlife Management
Huron County Gypsy Moth Suppression Program
Huron Pines RC&D Area

Ingham County Health Department, *Division of Environmental Health*
Kent County Gypsy Moth Suppression Program
Livingston County Gypsy Moth Coordinator
Macomb County Gypsy Moth Suppression Program
Mecosta County Gypsy Moth Suppression Program
Michigan Department of Agriculture, *Pesticide and Plant Pest Management Division*
Michigan Department of Natural Resources, *Forest Management Division*
Michigan Department of Natural Resources, *Region I Headquarters*
Michigan Department of Natural Resources, *State Forester*
Michigan Department of Transportation
Michigan State University Extension, *Gypsy Moth Education Program*
Midland County Gypsy Moth Suppression Program
Muskegon County Gypsy Moth Suppression Program
Newaygo County Gypsy Moth Suppression Program
Oakland County Cooperative Extension
Oceana County Gypsy Moth Suppression Program
Ottawa Soil and Water Conservation District
Roscommon County Gypsy Moth Suppression Program
Village of Beverly Hills Michigan
Wexford County Gypsy Moth Coordinator

Minnesota
Cooperative Extension Service *Fillmore County*
Cooperative Extension Service *Lincoln County*
Cooperative Extension Service *Martin County*
Cooperative Extension Service *McLeod County*
Cooperative Extension Service *Todd County*
Cooperative Extension Service *Wright County*
Minnesota Department of Agriculture, *Plant Protection Division*
Minnesota Department of Natural Resources, *Director*
Saint Louis County Land Department

Mississippi
Mississippi Department of Agriculture and Commerce, *Plant Pest Division*

Missouri
Big Springs RC&D Area
Cooperative Extension Service *Barry County*
Cooperative Extension Service *Buchanan County*
Cooperative Extension Service *Dallas County*
Cooperative Extension Service *Hold County*
Cooperative Extension Service *Lincoln County*
Cooperative Extension Service *Linn County*
Cooperative Extension Service *Madison County*
Cooperative Extension Service *Miller County*
Cooperative Extension Service *Morgan County*
Cooperative Extension Service *Ozark County*
Cooperative Extension Service *Putnam County*
Cooperative Extension Service *Reynolds County*
Cooperative Extension Service *St. Clair County*
Cooperative Extension Service *St. Genevieve County*
Cooperative Extension Service *Sullivan County*
Cooperative Extension Service *Washington County*
Cooperative Extension Service *Webster County*
Department of Agriculture
Department of Conservation, *Forestry Division*
Department of Conservation, *State Forester*
Department of Natural Resources, *Natural History Program*
Missouri Department of Conservation, *Natural History Division*
University of Missouri Extension Service

Nebraska
Nebraska Department of Agriculture, *Bureau of Plant Industry*

Nevada
Nevada Division of Agriculture, *Bureau of Plant Industry*

New Hampshire
Department of Resources and Economic Development, *Division of Forests and Lands, Director*
Wildlife Management Institute

New Jersey
Bergen County Parks
Bureau of Forest Management
Department of Agriculture, *Division of Plant Industry*
Department of Environmental Protection
Division of Parks and Forestry, *Department of Forestry Services*

Mercer County Park Commission
New Jersey Forest Service, *State Forester*
Rutger's Cooperative Extension
Township of East Hanover, *Environmental Commission*
Warren County Soil Conservation District, *New Jersey Natural Resources Conservation Program*

New Mexico
New Mexico Department of Game and Fish
New Mexico State Forestry

New York
Cooperative Extension Service *Cortland County*
Cooperative Extension Service *Erie County*
Cooperative Extension Service *Nassau County*
Cooperative Extension Service *Oswego County*
Directorate of Engineering and Housing
Dutchess County Cooperative Extension
New York City Department of Environmental Protection
New York Office of Parks, Recreation, and Historic Preservation
New York Power Authority
New York State Department of Environmental Conservation, *Division of Lands and Forests, Director*
New York State Office of Parks, Recreation and Historic Preservation
Ulster County Environmental Management Council

North Carolina
Department of Environment, Health, and Natural Resources, *Division of Forest Resources*
MOTSU Facilities Engineering Division
New Hanover County Cooperative Extension Service
North Carolina Department of Administration, *State Clearinghouse*
North Carolina Department of Agriculture, *Plant Industry Division*
North Carolina Natural Heritage Program, *Division of Parks and Recreation*
North Carolina State University, *Extension Service*

Ohio
City of Cleveland Heights
Cleveland Metro Parks
Cleveland Museum of Natural History
Clinton County Conservation District
Colerain Township Parks
Cooperative Extension Service *Fulton County*
Cooperative Extension Service *Athens County*
Cooperative Extension Service *Brown County*
Cooperative Extension Service *Butler County*
Cooperative Extension Service *Clark County*
Cooperative Extension Service *Columbiana County*
Cooperative Extension Service *Cuyahoga County*
Cooperative Extension Service *Geauga County*
Cooperative Extension Service *Hardin County*
Cooperative Extension Service *Jackson County*
Cooperative Extension Service *Lake County*
Cooperative Extension Service *Lucas County*
Cooperative Extension Service *Mahoning County*
Cooperative Extension Service *Muskingum County*
Cooperative Extension Service *Trumball County*
Cooperative Extension Service *Williams County*
Hamilton County Park District
Lake Metro Parks, *Natural Resources Department*
Metro Parks
Mohican Memorial State Forest
Muskingum Watershed Conservation District
Ohio Department of Agriculture, *Plant Industry*
Ohio Department of Natural Resources, Division of Forestry, *State Forester*
Ohio Division of Wildlife
Ohio Environmental Protection Agency
Ohio Farm Bureau
Ohio State University Extension, *Agriculture and Natural Resources*
Summit County Health Department

Oklahoma
Oklahoma Department of Agriculture, *Forestry Division*
Oklahoma Department of Agriculture, *Plant Industries Division*

Oregon
Coos County Health Department
Curry County Weed Control
Department of Public Works
Lane County Noxious Weed Control Board
Oregon Department of Agriculture
Oregon Department of Forestry

Pennsylvania
Cooperative Extension Service *Bedford County*
Cooperative Extension Service *Berks County*
Cooperative Extension Service *Dauphin County*
Cooperative Extension Service *Huntingdon County*

Cooperative Extension Service *Lehigh County*
Cooperative Extension Service *Lycoming County*
Cooperative Extension Service *McKean County*
Cooperative Extension Service *Monroe County*
Cooperative Extension Service *Northumberland County*
Cooperative Extension Service *Sullivan County*
Cooperative Extension Service *Susquehanna County*
Cooperative Extension Service *Union County*
Cooperative Extension Service *York County*
County of Lackawanna, *Department of Parks and Recreation*
Department of Environmental Resources, *Bureau of Forestry, Director*
Division of Forest Protection, Bureau of Forestry
Mount Pleasant Township
Municipal Authority of West Moreland County
Penn Soil RC&D Area
Penn State Cooperative Extension Service
Penns Corner RC&D Area
Pennsylvania Department of Environmental Resources, *Bureau of Forestry*
Pennsylvania Department of Parks and Recreation
Pennsylvania Fish and Boat Commission
Pennsylvania Forest Pest Management
Pennsylvania Game Commission
Schuylkill Conservation District
Westmoreland Conservation District

Rhode Island
Providence Water Supply Board
Rhode Island Department of Environmental Management, *Division of Forest Environment, Chief*
Rhode Island Division of Agriculture

South Carolina
Department of Plant Industry
Ninety Six RC&D
South Carolina Forestry Commission

South Dakota
Department of Agriculture, *Office of Plant Industry*
Division of Forestry

Tennessee
Tennessee Department of Agriculture, *Division of Plant Industries*
Tennessee Division of Forestry
Tennessee Wildlife Resource Agency

Texas
Texas Department of Agriculture, *Pest Management*
Texas Forest Service

Utah
Salt Lake County Health Department
Utah Department of Agriculture
Utah Office of Planning and Budget

Vermont
Agency of Natural Resources, *Department of Forests, Parks and Recreation*
Department of Forests, Parks and Recreation, *Division of Forests, Director*
Ferrisburg Conservation Commission
Hartland Conservation Commission
Hinesburg Conservation Commission
Rutland Natural Resource Conservation District
Stowe Conservation Commission
Vermont Cooperative Extension, *University of Vermont*
Windham Natural Resource Conservation Division
Woodstock Conservation Commission

Virginia
Albemarle County
Charles City County
Chesterfield County
County Gypsy Moth Program, *County Government Center*
County of Fauquier Gypsy Moth Office
County of Frederick, Gypsy Moth Coordinator
County of Shenandoah Gypsy Moth Office
Department of Environmental Management
Department of Parks, Recreation and Community Resources
Department of Public Works, *Operations Division, Gypsy Moth Program*
Dinwiddle County
Fairfax County Gypsy Moth Office
Fairfax County Park Authority, *Environmental Services*
Fairfax ReLeaf
Fauquier County
King William County
Nelson County

Northern Virginia Planning District Commission
Page County
Parks and Recreation
Potomac Edison Company
Powhatan County Gypsy Moth Program
Prince William County Gypsy Moth Program
Rockbridge County Gypsy Moth Program
Rockingham County Gypsy Moth Program
Virginia Cooperative Extension Service, *Virginia Polytechnic Institute and State University*
Virginia Department of Agriculture and Consumer Services
Virginia Department of Forestry
Virginia Game and Inland Fisheries
Warren County Gypsy Moth Program
York County Department of Environment Resources
York County Gypsy Moth Program

Washington

CEP/Thurston County
City of Kent Public Works
Cowlitz County Noxious Weed Control Board
Department of Ecology
Department of Natural Resources, *Aquatic Resources*
Department of Natural Resources, *Forest Health*
Port of Grays Harbor, Marine Operations
Port of Tacoma, *Operations Management*
Port of Vancouver, *Marine Terminal Superintendent*
Puget Sound Water Quality Authority
Washington Department of Agriculture
Washington Department of Transportation, *Roadside Maintenance*
Washington Extension Service *Walla Walla County*
Washington Public Ports Association
Washington State Department of Fisheries
Washington State Department of Health
Washington State Parks and Recreation Commission

West Virginia

Cooperative Extension Service *Hancock County*
Cooperative Extension Service *Harrison County*
Forestry Division
Hardy County Extension Agent
State Lands Management, *Division of Forestry*
Upshur County Extension Agent
West Virginia Department of Agriculture
West Virginia Department of Commerce, Labor and Environmental Resources, *Division of Forestry, Administration Forester*
West Virginia Department of Energy
West Virginia Department of Natural Resources
West Virginia Forestry Association
West Virginia RC&D Association

Wisconsin

Cooperative Extension Service *Eau Claire County*
Cooperative Extension Service *Jefferson County*
County Horticulturist
Department of Natural Resources, *Northwest District Headquarters*
Lake States Forestry
Lincoln County Forestry Land and Park Department
University of Wisconsin Cooperative Extension
Wisconsin Department of Agriculture, Trade and Consumer Protection
Wisconsin Department of Natural Resources, *Chief of Protection and Reforestation*
Wisconsin Department of Natural Resources, *Hayward State Nursery*
Wisconsin Department of Natural Resources, *Kettle Moraine State Forest*
Wisconsin Department of Natural Resources, *Western District Headquarters*

Wyoming

Wyoming State Forestry Division

Puerto Rico

Department of Natural Resources
El Caribe RC&D

American Indian Nations, Tribes, and Related Agencies

Alaska

Metlakatla Indian Community

Arizona

Hopi Tribal Council
White Mountain Apache Tribal Council

California
USDA, Bureau of Indian Affairs

Connecticut
Mashantucket Pequot Tribe

Maine
Houlton Band of Maliseet Indians
Passamaquoddy IR, Forestry Department
Penobscot Indian National Department of Natural Resources

Minnesota
Mille Lacs Band of Chippewa Indians
Mille Lacs Band of Ojibwae
USDI, Bureau of Indian Affairs, *Minnesota Area Office*

Montana
USDI, Bureau of Indian Affairs, *Forestry*

Nevada
Duckwater Shoshone Tribal Council

New York
Teatown Lake Reservation
Seneca Nation of Indians
St. Regis Mohawk Tribe, Environmental Division

North Dakota
USDI, Bureau of Indian Affairs, *Fort Berthold Agency*

Oregon
Intertribal Timber Council

Rhode Island
Narragansett Indian Tribe

Virginia
USDI, Bureau of Indian Affairs

Washington
Stillaguamish Tribe
Suquamish Indian Nation
Tulalip Tribes

Wisconsin
Bad River Band of Lake Superior Chippewas
Menominee Tribal Enterprises
USDI, Bureau of Indian Affairs, *Great Lakes Agency*

Foreign Agencies

Australia
Australian Quarantine and Inspection Service, *Department of Primary Industries and Energy*

Belgium
Biblioteek Voor Hedendaagse Dokumentatie, *Parklaan 2*

Canada
Agriculture Canada
Atmospheric Environmental Service
British Columbia Forest Service, *Silviculture Branch*
Canadian Forestry Service
Canadian Wildlife Service, *National Wildlife Research Center*
Co. of Simcoe Admin. Centre
Forestry Canada
Forestry Canada, Maritimes Region
Forestry Canada, Ontario Region
FPMI, Canadian Forest Service
Ministry of Natural Resources, *Policy Interpretation Coordination Section*
Ministry of the Environment
New Brunswick Department Natural of Resources
Nova Scotia Natural Resources
Ontario Ministry of Natural Resources
Research Branch - CLBRR
Town of Oakville, Parks and Recreation Department

New Zealand
New Zealand Ministry of Forestry

Organizations

Arizona
Arizona Toxics Information
Greenpeace
Vista II C/Club

Mailing List

Arkansas
- Arkansas Natural Heritage Commission
- Arkansas Nature Conservancy
- Forest Inholders Guarding Habitat Together (FIGHT)
- Ouachita Timber Purchasers Group
- Public Awareness Committee, Inc.
- Sierra Club Arkansas Chapter

California
- C.C.A.P.
- California Wilderness Coalition
- Californians for Alternatives to Toxics
- Mexican American Political Organization
- Mothers of East LA, Santa Isabel Chapter
- National Audubon Society
- Northcoast Environmental Center
- People for Healthy Forests
- Salmon River Concern Citizens
- Share, Care and Prayer

Colorado
- AAC
- American Birding Association, Inc.

Delaware
- Delaware Campground Owners Association
- Delaware Nature Education Society
- Delaware Nature Society
- Stafford Homeowners Association

District of Columbia
- American Forests
- Association of State and Territorial Health Officials
- Environmental Defense Fund
- Metropolitan Washington Council of Government
- National Association of Counties
- National Coalition Against the Misuse of Pesticides
- National Wildlife Federation
- Resources for the Future
- Save America's Forests
- Wilderness Society

Florida
- The International Family Recreation Association

Georgia
- American Forest and Paper Association
- Chattahoochee Nature Center
- Friends of the Mountains Advisory Board
- Georgia Appalachian Trail Club, Inc.
- Sandy Creek Nature Center
- Sautee-Nacoochee Community Association
- Savannah Tree Foundation
- Sierra Club, Greater Gwinnett

Idaho
- Kootenai Environmental Alliance

Illinois
- EI/MCS Support Group
- Illinois Native Plant Society
- Illinois Nature Preserves
- National Campers and Hikers Association
- Shawnee Audubon Society
- USA CERL
- Wildlife Society, *Illinois Chapter*

Indiana
- Alternative Forest Management, Inc.
- Heartwood
- Hoosier Environmental Council
- Indiana Campground Owners Association
- Indiana Forestry and Woodland Owners Association
- The Nature Conservancy
- Wildlife Society, *Indiana Chapter*

Iowa
- Trees Forever

Kansas
- Kansas Campground Association

Kentucky
- Kentucky Resources Council
- League of Kentucky Sportsmen, Inc.
- Nature Preserves Commission
- Society of American Foresters, *East Kentucky Chapter*

Maine
- Small Woodland Owners Association of Maine

Maryland
- Alliance for the Maryland Forest
- Chesapeake Bay Foundation
- Earth First!

Environmental Action Foundation
Environmental Concerns
Environmental Health Services
International Society of Tropical Foresters, Inc.
Izaak Walton League of America, Inc., *Maryland Division*
Maryland Forest Park and Wildlife
Maryland Campground Owners Association
Maryland Entomological Society
Maryland National Capital Park and Planning Commission
MCS Referral and Resources
Rachel Carson Council
Sierra Club
The Wildlife Society
Washington Suburban Sanitary Commission
Western Maryland Research and Education Center
WYS Research and Education Center

Massachusetts
Environmental Health Advocacy League (ENHALE)
Hancock Timber Resource Group
Massachusetts Association of Conservation Commission
Massachusetts Audubon Society
Massachusetts Forestry Association
New England Forestry Foundation, Inc.
Silent Spring Institute
The Trustees of Reservations

Michigan
Citizens for Alternatives to Chemical Contamination
Global ReLeaf of Michigan
Michigan Forest Assocation
Michigan United Conservation Club
Sierra Club, *Mackinac Chapter*
The Ecology Center
Wild Turkey Federation

Minnesota
Izaak Walton League of America, Inc., *Minnesota Division*

Missouri
Audubon Society of Missouri
Sierra Club, *Ozark Chapter*

New Hampshire
New Hampshire Timberland Owners Association
Wildlife Management Institute

New Jersey
Educational Information and Resource Center
The Nature Conservancy
New Jersey State Federation of Sportsmen's Clubs
North American Butterfly Association
Palisades Nature Association
Weis Ecology Center

New York
Campground Owners of New York
Centers for Nature Education
Constitution Marsh Sanctuary
Great Neck Outdoor Environmental Center
Greenburg Nature Center
High Rock Park Conservation Center
National Council of Paper Industry Air and Stream Improvement
New York Coalition for Alternatives to Pesticides
Pok-O-Moonshine Outdoor Education Center
Rodger Tory Peterson Nature Center
Sharpe Environmental Center
Stony Kill Environmental Center
Tackapausha Museum and Preserve
The Adirondack Council
Thompson Pond Project

North Carolina
Agricultural Research Center
CONC/Sierra Club
North Carolina Nature Conservancy
RUST Environment and Infrastructure
Southern Appalachian Biodiversity Project
Southern Environmental Law Center
Trout Unlimited

Ohio
ACRT, Inc.
American Free Tree Program
Holden Arboretum
Ohio Christmas Tree Association, Inc.
The Nature Conservancy
Sierra Club, *Northeast Ohio Group*

Oregon
1000 Friends of Oregon

Lane County Audubon Society
Native Forest Council
Northwest Coalition for Alternatives to Pesticides
Oregon Natural Resources Council
Oregon Small Woodlands Association
Oregonians for Food and Shelter
Sierra Club, *Oregon Chapter*
The Rainland Fly Casters
The Xerces Society
Western Environmental Law Center

Pennsylvania
Asbury Woods Nature Center
Bradford Naturalist Club
CEASE, Inc.
Creative Services
Ecogen, Inc.
Forest Management Center
Hawk Mountain Sanctuary
Izaak Walton League of America, Inc., *Pennsylvania Division*
McKeever Environmental Learning Center
PAW, Mid-Atlantic Biodiversity Project
Pennsylvania Campground Owners Association
Pennypack Ecological Restoration Trust
Seneca Highlands Association
Sierra Club
Trout Unlimited, *Pennsylvania Council*

South Carolina
South Carolina Campground Owners

Tennessee
Kentucky-Tennessee Society for American Foresters
Wildlife Society, *Tennessee Chapter*

Texas
Bat Conservation International
Houston Sierra Club
Texas Committee on Natural Resources

Vermont
Audubon Council, *Vermont*
Earth First!
Federated Garden Clubs of Vermont
Keewaydin Environmental Education Center
Trout Unlimited
Vermonters for Environmental Health
Woodland Owners' Association

Virginia
Du Pont Nature Club
Living Education Center for Ecology and the Arts
Lorton Federation of Communities
Reston Association
Sierra Club, *Virginia Chapter*
Virginians for Wilderness

Washington
Northwest Christmas Tree Association
Sierra Club, *Cascade Chapter*
South Puget Environmental Education Clearinghouse
Washington Forest Protection Association
Washington Toxics Coalition

West Virginia
Appalachian Trail Conference
Mountain Aquaculture and Producers Association
Sierra Club, *West Virginia Chapter*

Wisconsin
American Pulpwood Association
Kemp National Resources Station
Ruffed Grouse Society
Sierra Club, *Midwest Region*
The Lake States Forestry Alliance

Canada
Canadian Earthcare Society
Society Targeting Overuse of Pesticides (STOP)

Libraries

In addition to the libraries listed, this final environmental impact statement has been sent by the U. S. Government Printing Office to Federal depository libraries across the United States.

California
Humboldt State University Library

Colorado
Colorado State University Library

Florida
University of Florida Marston Science Library

Georgia
University of Georgia Science Library

Maine
University of Maine, *Raymond H. Folger Library*

Maryland
USDA National Agricultural Library Headquarters

Massachusetts
State Library of Massachusetts

North Carolina
Perkins Library

Oregon
Oregon State Library
South Oregon State College Library
University of Oregon Library

Vermont
Bailey-Howe Memorial Library

Washington
Eastern Washington University, *JFK Library*
University of Washington, *Forest Resource Library*
University of Washington, *Suzzallo Library*
Washington State Library
Whitman College, *Penrose Memorial Library*

West Virginia
Five Rivers Public Library
Western Virginia University, *Evansdale Library*

Canada
Forestry Canada Library Service
Ministry of Environment Library
Ministry of Forests and Lands Library

Individuals

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Edwin Auerbach, Jr.
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Glen Comeaux
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Guy Karr
Neil Letson
Robert Reid

Alaska
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Gary Miner
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Bill Ostrofsky
Stephen Pelletier
Andrew Pottle
Joel Reed
Hugh Roak
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David Struble
James S. Trask
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Ronald Wilson
Charlie Winfree
David Workman
Arthur Yagel
Cathy Zivkovich

Wisconsin

Charles Adams
R. Bruce Allison
Ray Amiel
Steve Berg
John Borkenhagen
Frank Bremser
Bill Brener
James Bruce
Richard Camp
L. P. Campbell
JoAnne Cruse
John Culhane
Dan Dessecker
Duane Dupor
James Grafelman
Raymond Hajewski
Tony Hallman
Jim Halvorson
Dan Heisler
Carl Hensley
Sally Hess-Samuelson
Charles Higgs
Robert Howe
Sue Jennings
Thomas Kautz
Carl Kietzmann
Randy Knapp
Chuck Koval
Steven C. Krause
Dan Kretz
Todd Lanigan
Richard Lindroth
Bryce Luchterhand

Peter Luxenhofer
Dick Meier
Kenneth Nelson
John E. Peck
Joy Perry
Perry Pierre
Chuck Pils
Allen Prey
Dan Pubanz
Thomas Rausch
Wendy H. Sanders
Jim Schmid
Dave Schumacher
Michelle Shafer
Marlene Skabroud
Steve Solheim
N. Spangenberg
Tom Steele
Edson Stevens
Jeffrey Stier
Alan T. Tracy
John Trobaugh
Douglas Tutor
Craig Ver Kuilen
Shane Weber
Daniel Weiss
William Wengeler
Wayne Wilson
Wayne Wood
Carl Zichella

Wyoming
Darrel L. Carruth
James Keller
John Larson
Tim McNary
Lia Spiegel
Jim Sweaney

Guam
John Lawrence

Puerto Rico
Ileana Echegoyen
Angel Gonzalez
Edgardo Gonzalez
Delcio Rivera

Australia
Dr. Michael Cole

Belguim
M. Dunn

Canada
William Andrews
Kevin Barber
Eric Bauce
Jon Bell
Harold Bielefeld
George Briggs
Nathalie Carisey
Jerry Carlson
Nelson Carter
R. F. DeBoo
Frank Dimock
Peter M. Hall
W. Hardy
Steve Holmes
Gordon Howse
John Hudak
M. M. Bohdan
Kowalyk
Mary Frances
LaMarche
Christopher Lewis
Murray Lockhart
D. Barry Lyons
Laszlo Magasi
Lloyd Manchester
Barry Manfield
Lynn McCarty
John McNeil
Linda Michaluk
Bob Mickle
Dan Miller
Andrew Morley
Vince Nealis
Diane Novlan
Fran Paterson
Bruce Pauli
V. C. Plowman
Garry Reusch
Paul A. Robertson
David Roden
Taylor Scarr
Al Schmidt
Malcom Shrimpton
Thomas Smith
Alice Solyma
Marie-Eve Varin
D. Wallace
Doreen Watler
Sandy Welsh
Gary Wilkins
Steve Wilkins
K. Wright

The Netherlands
Andre Dykstre

New Zealand
John Handisides

Chapter 8

Glossary

Oak leaves eaten by gypsy moth caterpillars, Saugus, Massachusetts, July 1894

Glossary

Terms are defined as they pertain to this environmental impact statement on the gypsy moth.

acetylcholine—a compound released at nerve endings, active in the transmission of the nerve impulse

acetylcholinesterase—an enzyme that occurs in nerve endings and prevents accumulation of acetylcholine; acetylcholinesterase inhibition results in acetylcholine accumulation, which impairs the nervous system (Doull and others 1980)

actinomycete—any bacterium in the order *Actinomycetales*, which contains filamentous branching bacteria of the genera *Actinomyces* and *Streptomyces*

active ingredient—(a.i.) the toxic part of an insecticide formulation

adverse-effect level—(AEL) signs of toxicity that must be detected by invasive methods, external monitoring devices, or prolonged systematic observations. Symptoms that are not accompanied by grossly observable signs of toxicity.

AEL—acronym for adverse-effect level

Agricultural Research Service—(ARS) a USDA agency that develops the means to protect trees in forests, parks, yards, and other nonforest environments; and conducts research to support activities against the gypsy moth

a.i.—abbreviation for active ingredient

alternative—one possible way to accomplish a proposed action; a way to manage the gypsy moth in the United States

amphipod—any of various small crustaceans in the order Amphipoda, with laterally compressed bodies found primarily in aquatic habitats; examples are sandhoppers, beach fleas, and skeleton shrimp

Animal and Plant Health Inspection Service—(APHIS) the joint-lead agency for this environmental impact statement on the gypsy moth; the USDA agency that enforces the national quarantine, coordinates with States on the National Gypsy Moth Survey, provides assistance to States to eradicate isolated infestations of the gypsy moth on 640 acres or less, develops new methods to improve gypsy moth quarantine and eradication practices, and conducts technology transfer activities

APHIS—acronym for Animal and Plant Health Inspection Service

ARS—acronym for Agricultural Research Service

arthropods—a large group of invertebrate animals that includes insects, spiders, and crustaceans

artificial spread—spread of the gypsy moth by other than natural means, for example, by insect life stages attaching to and being moved on recreational vehicles, automobiles, nursery stock, outdoor household articles, and cargo (USDA APHIS 1990)

Asian strain—refers to strains of the gypsy moth originating in the Far East, which have some females that can fly, and may have the capacity to establish in a broader host range, be larger, and hatch earlier than the European strain

atrophy—a decrease in the size of a cell, tissue, or organ, often associated with exposure to a toxic agent

Bacillus thuringiensis* var. *kurstaki—(*B.t.k.*) scientific name of a bacterium that is specifically pathogenic to caterpillars of many moths and butterflies; the active ingredient in biological

insecticides sold under the trade names Dipel, Foray, and Thuricide (USDA APHIS 1990)

basal area—a cross-sectional area of a tree determined from the diameter of the trunk at breast height; the total area of ground covered by trees measured at breast height (Lincoln and Boxshall 1987)

benthic—pertaining to the sea bed, river bed, or lake floor (Lincoln and Boxshall 1987)

bioassay—determination of the relative strength of a substance (e.g., drug, insecticide) by comparing its effect on a test organism with that of a standard preparation

BIU—acronym for billion international units

B.t.k.—abbreviation for *Bacillus thuringiensis* var. *kurstaki*

canopy—the uppermost layer of foliage in forest vegetation, formed by the crowns of trees (Lincoln and Boxshall 1987)

carcinogen—a chemical capable of inducing cancer

caterpillar—the soft-bodied larva of the gypsy moth or other moth, butterfly, or sawfly (Lincoln and Boxshall 1987)

cfu—acronym for colony forming units

chironomid—an ecologically important group of aquatic insects belonging to the family Chironomidae (order Diptera), often occurring in high densities and diversity, and feeding on a great variety of organic substrates. Chironomids are important prey of most aquatic predators.

chitin—a horny substance made of a complex carbohydrate similar to cellulose that is the main component in the skin of insects, spiders, and crustaceans

cholinergic—refers to nerve cells that release acetylcholine

cholinesterase—a group of enzymes that degrade acetylcholine and similar compounds. Cholinesterases that occur in nerve tissues have a clear function. Other cholinesterases, such as those occurring in red blood cells or plasma, do not have a clear function but are used as indicators of insecticide exposure.

chronic exposure—long-term exposure studies often used to determine the carcinogenic potential of chemicals; these studies are usually performed in rats, mice, or dogs and extend over the average lifetime of the species; for example, chronic exposure for a rat is 2 years

circadian rhythm—an influence of the time of day on the rate of metabolism of foreign compounds, often observed in a given animal species; a variation in the metabolic rate often correlated with variations in endocrine functions, as influenced by the light-dark cycle to which the animal is exposed

cladoceran—small aquatic crustaceans in the order Cladocera; water fleas

coliforms—bacteria that indicate recent fecal contamination of water

colony forming unit—(cfu) an index of bacterial levels in a medium such as air or water; a cfu represents a collection of a droplet or particulate from air that contains one or more viable spores or vegetative cells of *B.t.k.*

compliance agreement—a written agreement between APHIS Plant Protection and Quarantine and a person who grows, handles, or moves regulated articles to comply with APHIS regulations (USDA APHIS 1990)

congenital—refers to conditions that are present at birth, regardless of their cause

conidium—(pl. conidia) an asexual spore produced by fungi

conjunctiva—the thin mucous membrane that lines the eyelids

connected actions—exposure to other chemical and biological agents in addition to exposure to a treatment agent used to control the gypsy moth

connective tissue—the tissue that binds together and supports the various structures of the body

contaminants—for chemicals, impurities present in a commercial grade chemical; for biological agents, other agents that may be present in a commercial product

control—to maintain or try to maintain a population density of insects or other undesirable animals below the point where injury to man's interests occurs (Nichols 1989)

cooperative project—a management project conducted by a State or Federal agency, under agreement and with financial and technical assistance of the U.S. Department of Agriculture, to control forest diseases and insects, such as the gypsy moth

Cooperative State Research, Education, and Extension Service—(CSREES) a USDA agency that administers a research grants program including gypsy moth research, plans cooperative research projects through the State Agriculture Experiment Station System, and coordinates information and education activities

cooperator—a State or Federal agency that enters into an agreement with the U.S. Department of Agriculture, to conduct a cooperative project

copepod—any of small marine or freshwater crustaceans in the class Copepoda, exhibiting great diversity in form and life history

corixid—any of insects in the family Corixidae (order Hemiptera); also referred to as true water bugs

critical habitat—an area determined by the U.S. Fish and Wildlife Service to be essential to the conservation of threatened or endangered species and that may require special management considerations or protection

crown condition—a combination of tree crown density, coloration, leaf-rolling, mortality, or other factors that provide an indication of tree health

crustaceans—organisms such as crabs, lobsters, shrimp, crayfish, wood lice, pill bugs, and water fleas, that have hard exoskeletons made of chitin, as do other arthropods

CSREES—acronym for Cooperative State Research, Education, and Extension Service

cumulative effects—effects attributable to exposures that may last for several days to several months, or effects resulting from gypsy moth program activities that are repeated more than once during a year or for several consecutive years

DDVP—abbreviation of the chemical name for dichlorvos—2,2 dichloroethenyl dimethyl ester phosphoric acid—an insecticide contained in some gypsy moth traps

defoliation—noticeable loss of foliage due to feeding by insects, such as gypsy moth caterpillars; light defoliation is normal background defoliation of less than 30 percent, moderate defoliation is 30 to 60 percent, heavy defoliation is greater than 60 percent

defoliation survey—visually examining trees from the ground or the air, to detect defoliation

degradation—breakdown of a compound by physical and chemical or biochemical processes, into basic components with properties different from those of the original compound

delimiting survey—using pheromone-baited traps to determine the approximate size of an infested area

dermal—pertaining to the skin

detection survey—using pheromone-baited traps to determine whether the gypsy moth is present and where delimiting may be necessary

detritus—fragmented particulate organic matter resulting from the decomposition of plant and animal remains (Lincoln and Boxshall 1987)

developed forest—privately owned, forested, residential areas

dichlorvos—another name for DDVP

diflubenzuron—the active ingredient of chemical insecticide formulations sold under the trade name Dimilin. It acts as a growth regulator by interfering with chitin synthesis and preventing molting in gypsy moth caterpillars, some other immature insects, and crustaceans (USDA APHIS 1990)

Dimilin—trade name of diflubenzuron formulations registered for use against the gypsy moth

dipteran—an insect belonging to the order Diptera, which includes flies and mosquitoes

direct effect—the reaction of an organism after exposure to a chemical or nonchemical agent that is not mediated through another organism. For example, caterpillars that eat leaves with diflubenzuron on them fail to molt, and die as a result of their direct exposure to this insecticide; the direct effect of an unchecked gypsy moth infestation could be a change in species composition of trees.

disparlure—a synthetic version of the pheromone produced by female gypsy moths to attract males for mating

diurnal rhythm—normal changes in the body that occur during the day, most diurnal variations have been shown to be related to eating and sleeping habits

dominant trees—trees with crowns extending above the general level of the canopy and receiving full light from above and from the side (Smith 1986)

dose-response assessment—a description of the relationship between the dose of a chemical and the occurrence or intensity of an effect

draft environmental impact statement—a detailed written statement of effects expected as a result of a major Federal action that is released to the public and other agencies for review and comment, as required under Section 102(2)(c) of the National Environmental Policy Act

EC_{50}—acronym for median effective concentration

ecology—the study of the interrelationships between living organisms and their environment (Lincoln and Boxshall 1987)

ecosystem—living organisms interacting with each other and with their physical environment, usually described as an area for which it is meaningful to address these interrelationships

ecosystem management—a holistic approach to achieving productive healthy ecosystems by blending social, physical, economic, and biological needs and values

egg mass survey—visually examining an area in a systematic manner, either (1) outside the generally infested area, to obtain evidence that gypsy moths are present and reproducing, or (2) in an infested area, to assess the population density

EIS—acronym for environmental impact statement

enantiomer—refers to molecules that are structurally identical except for differences in the three-dimensional configuration

endangered species—a Federal designation for any species that is in danger of extinction throughout all or a significant part of its range. The Federal list of endangered species is maintained by the Secretary of the Interior.

endpoints—components of an ecosystem that indicate its sensitivity to the type of disturbance expected from the gypsy moth or treatments; five endpoints were selected for the ecological risk assessment: nontarget organisms; forest condition; water quality; microclimate; and soil fertility and productivity

Entomophaga maimaiga Humber, Shimazu, and Soper—scientific name for a fungus that causes disease in gypsy moth caterpillars

environmental analysis—an investigation of alternative actions and their predictable environmental effects through a systematic interdisciplinary approach, which ensures the integrated use of the natural and social sciences and the environmental design arts in planning and in decisionmaking that may have an impact on the human environment

environmental assessment—a concise public document written by a Federal agency to provide evidence and disclose the rationale for determining whether to prepare an environmental impact statement or a finding of no significant impact for a planned action

environmental impact statement—(EIS) a detailed public document written by a Federal agency to disclose significant environmental impacts that would result from a planned action, and used to make decisions about the action

epidemiology—a branch of science that deals with the incidence, distribution, and control of disease in a population (Merriam-Webster 1991)

epizootic—occurrence of a disease in animals that is widely prevalent and spreads rapidly

eradication—the strategy of eliminating an isolated infestation of the gypsy moth

European strain—the strain of the gypsy moth historically found in Western Europe and the original source of the North American population, which has females that do not fly

evaluation—a gypsy moth survey to determine the need for treatment, or to determine the effectiveness of treatment

exclusion—a policy pursued by APHIS to prevent animal and plant pests and diseases, including the gypsy moth, from being introduced into the United States

exotic—refers to all species of plants and animals not naturally occurring, either now or in the past, in any ecosystem of the United States (Executive Order 11987, May 24, 1977)

exposure—skin contact, inhalation, or ingestion of a substance that may have a harmful effect

exposure assessment—the process of estimating the extent to which a population will come into contact with a chemical or biological agent

fecal—of or relating to feces (solid bodily waste)

final environmental impact statement—a detailed written statement of the analysis of a major Federal action, released to the public as required under sec. 102 (2)(c) of the National Environmental Policy Act

financial assistance—money provided by the Forest Service and APHIS to Federal and State agencies through several pest control or management programs to suppress, eradicate, or slow the spread of the gypsy moth. On Federal lands the costs of gypsy moth projects are paid in full. On State and private lands costs may be shared with State cooperators. See *technical assistance* for other assistance provided.

forest condition—species composition, tree growth rates and mortality rates, productivity, and degree of insect damage

forest cover type—a description based on and named after the tree species that forms a plurality of the basal area in a stand. Other tree species may also be part of the stand.

Forest Service—the lead agency for this environmental impact statement; the largest USDA agency, which conducts research and develops the means to control the gypsy moth in forests. It conducts surveys and evaluations on lands managed by other Federal agencies. It also helps State and other Federal agencies to conduct detection surveys, evaluation, and suppression; to test and transfer technology designed to improve gypsy moth control and reduce damage; and to conduct eradication on

Federal or adjacent land, and on non-Federal land for infestations of more than 640 acres

forest type group—a grouping of forest cover types for inventory, mapping, or other purposes

forestomach—the front or foremost portion of the stomach in animals

formulation—a commercial preparation of a chemical including any inert ingredients or contaminants

frass—fecal excrement of gypsy moth caterpillars

generally infested area—(regulated or quarantined area) the area in the eastern United States where the European strain of the gypsy moth is considered to be permanently established; also the area quarantined by APHIS and the States. All life stages are present, and populations are continuous. Population outbreaks occur, and defoliation is common. In 1994, the area extended from Maine to northern North Carolina and west to West Virginia, Ohio, and Michigan.

geometric mean—the measure of an average value often applied to numbers for which a log normal distribution is assumed

Gypchek—trade name for a biological insecticide containing gypsy moth nucleopolyhedrosis virus, which is registered and produced by the Forest Service and APHIS

gypsy moth—all life stages of the Asian and European strains of the insect with the scientific name *Lymantria dispar* (L.), previously *Porthetria dispar* (L.)

habitat—the place or type of site where a plant or animal naturally or normally lives and grows (Merriam-Webster 1991)

half-life—the time required for the concentration of a chemical to decrease by half of the original concentration (the longer the half-life, the more persistent a chemical is considered to be)

hazard—adverse effects to humans or the environment as a result of exposure to the gypsy moth or treatments; compare *risk*

hazard identification—the process of identifying the array of potential effects that an agent may induce in an exposed population

hazard quotient—the ratio of the estimated level of exposure to the risk reference value or some other index of acceptable exposure. A hazard quotient greater than one raises concern.

hematological—pertaining to the blood

hemoglobin—an iron-containing respiratory pigment in red blood cells of vertebrates

herbaceous—relating to plants that have nonwoody stems and that die down annually

herbivorous insect—an insect that eats plants or plant material; the gypsy moth is an herbivorous insect because it eats leaves

homopteran—an insect in the order Homoptera, which includes aphids, scale insects, and cicadas

host—a living organism that provides subsistence or lodging for another organism

hymenopteran—any of highly specialized insects in the order Hymenoptera, usually with four membranous wings, the abdomen borne on a slender pedicel, and associated with large colonies and complex social organization; includes bees, wasps, ants, ichneumon flies, sawflies, and gall wasps (Merriam-Webster 1991)

immunocompetent—having normal immune function

immunocompromised—having an impaired immune system, such as people with HIV or AIDS

indirect effect—the reaction of an organism to a change in the environment that is a direct result of exposure to a chemical or nonchemical agent. For

example, wasps that prey on caterpillars that eat leaves with diflubenzuron on them could obtain diflubenzuron that the caterpillars ate, thus being exposed indirectly to the chemical; the indirect effect of an unchecked gypsy moth infestation could be the change in the bird community that results from the change in woodland structure, a direct effect of the gypsy moth.

inert ingredients—additives in insecticide formulations that do not affect the organism targeted but are added for a variety of reasons, such as to stabilize the formulation, to improve its weatherability, or to prevent growth of contaminating microorganisms

infestation—the presence of the gypsy moth and an indication of a reproducing population, based on the results of surveys

infested area—isolated infestation or generally infested area

inhalation—the act of breathing

innocuous—something that produces no injury; harmless; inoffensive (Merriam-Webster 1991)

instar—a stage between molts in the development of the gypsy moth caterpillar and other arthropods

integrated pest management—(IPM) selecting strategies to manage pest-host systems for specific objectives. It includes planning, detection, evaluation, monitoring, establishing acceptable damage thresholds, and use of appropriate management practices to prevent or control pest-caused damage and losses.

interdisciplinary team—a team of varied resource specialists with different professional backgrounds who conduct an environmental analysis; members of the interdisciplinary team who prepared this environmental impact statement are listed in *chapter 5*, Preparers

invertebrates—animals without a spinal column, such as insects, spiders, and crustaceans

in vivo—in the living body of a plant or animal (Merriam-Webster 1991)

IPM—acronym for integrated pest management

isolated infestation—a defined area infested with the gypsy moth outside the generally infested area; or, a defined area infested with the Asian strain of the gypsy moth within the generally infested area

issue—a public concern or significant problem that might occur when the gypsy moth is present or treatments are applied

larva—stage in development between hatching and attaining adult form (Lincoln and Boxshall 1987)

larval survey—placing tar paper, burlap, or similar material around the trunks of susceptible trees, to create hiding places for gypsy moth caterpillars so they can be captured and counted

LC_{50}—acronym for lethal concentration$_{50}$

LD_1—acronym for lethal dose$_1$

LD_{50}—acronym for lethal dose$_{50}$

lepidopteran—any of insects in the order Lepidoptera, characterized by adults with two pairs of scale-covered wings and coiled sucking mouthparts, including moths and butterflies

lethal concentration$_{50}$—(LC_{50}) a calculated concentration of a toxicant in air (or water) to which exposure for a specific length of time is expected to cause death in 50 percent of a defined test animal population

lethal dose$_1$—(LD_1) the dose of a chemical or biological agent calculated to cause death in 1 percent of a defined test animal population

lethal dose$_{50}$—(LD_{50}) the dose of a chemical or biological agent calculated to cause death in 50 percent of a defined test animal population

life stage—a distinctive period in an insect's life (Nichols 1989). Life stages of the gypsy moth are egg in an egg mass, larva or caterpillar, pupa, and adult moth.

LOAEL—acronym for lowest-observed-adverse-effect level

lowest-observed-adverse-effect level—(LOAEL) the lowest measured amount of a chemical that produces significant increases in frequency or severity of adverse effects in an exposed human population

macroinvertebrates—invertebrates large enough to be seen with the unaided eye

management practice—a specific act, measure, course of action, or treatment

mass trapping—using pheromone-baited traps to catch all or nearly all the male gypsy moths in an area having low gypsy moth populations

mast—the fruit and seeds of trees and other forest vegetation eaten by wildlife. Hard mast includes nuts and seeds (such as acorns, walnuts, hickory nuts, maple seeds); soft mast is fruit (such as apples, blackberries, wild grapes).

mating disruption—saturating an area with gypsy moth pheromone to confuse male gypsy moths, thereby preventing them from locating and mating with females

median effective concentration—(EC_{50}) the concentration of a substance that results in some effect being exhibited by 50 percent of the test organisms

methemoglobinemia—a rare blood disorder in which there is a deficiency of the enzyme that turns methemoglobin into hemoglobin (methemoglobin differs from hemoglobin in being unable to combine reversibly with oxygen)

microclimate—the climate of the immediate surroundings or habitat, differing from the macroclimate, as a result of the influences of local topography, vegetation, and soil (Lincoln and Boxshall 1987)

microinvertebrates—invertebrates too small to be seen without magnification

microlepidopterans—a general term for the most primitive families of moths whose members usually have the smallest body sizes among lepidopterans (Nichols 1989)

mineralization—conversion of an organic substance into an inorganic substance as a result of microbial decomposition

molting—the process of shedding an old skin and creating a new one, as an insect grows or changes in form

monitor—to observe or check that treatments are carried out as planned, or to determine whether effects of treatments are those that were predicted

Monte Carlo simulation—a technique used to simulate systems with probabilistic elements. One or more variable in a Monte Carlo simulation is determined by drawing a random number from a probability distribution (such as the normal or uniform distribution), which describes the natural variation in that variable.

most sensitive effect—the adverse effect observed at the lowest dose of a substance—an important concept in risk assessments. If the most sensitive effect is prevented, no other effects will develop.

multiple chemical sensitivity—a syndrome that affects individuals who are extremely sensitive to chemicals at extremely low levels of exposure

multistoried stand—a stand of trees that is characterized by three or more distinctly different sizes

mutagenicity—the ability of a substance (mutagen) to cause genetic damage, that is, damage to DNA or RNA (mutation); mutations can lead to birth defects, miscarriages, or cancer

nanogram—(ng) one billionth of a gram

National Environmental Policy Act—(NEPA) Act of 1969 (42 U.S.C. 4321 (note)) established a national policy that encourages harmony between man and the environment; requires that Federal agencies proposing legislation or a major action use a systematic interdisciplinary approach to planning and decisionmaking, and prepare a detailed statement that includes the following: the environmental impact of the proposed action, any adverse environmental effects that cannot be avoided, alternatives to the proposed action, the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and any irreversible and irretrievable commitments of resources

National Gypsy Moth Survey—a minimal detection survey administered by APHIS in cooperation with the States, to detect isolated infestations of the gypsy moth outside the generally infested area (USDA APHIS 1990)

natural landmark—a site on the National Registry of Natural Landmarks, administered by the National Park Service, U.S. Department of the Interior, preserved as an outstanding example of plant or animal communities, geological features, scenic grandeur, or other attribute (USDA Forest Service 1990a)

natural spread—movement of gypsy moths from an infested area: (1) of first instar larvae by wind, (2) of larger larvae by crawling, (3) of adult females of the European strain by crawling, (4) of some adult females of the Asian strain by flying

necropsy—examination of a body after death, usually refers to a gross examination of the major organs

nematodes—elongated cylindrical worms that are parasitic in animals or plants or free-living in soil or water (Merriam-Webster 1991)

neotropical migrant—a bird that nests in North America but migrates to the neotropics (South America, Central America, and Caribbean) during winter

NEPA—acronym for National Environmental Policy Act

neuropathy—damage to the peripheral nervous system

ng—abbreviation for nanogram

NIOSH—acronym for the National Institute for Occupational Safety and Health

NOAEL—acronym for no-observed-adverse-effect level

NOEL—acronym for no-observed-effect level

no-observed-adverse-effect level—(NOAEL) the highest measured amount of a chemical at which no increase in frequency or severity of adverse effects is observed in an exposed human population when compared with a control; effects may be produced, but they are not considered to be adverse

no-observed-effect level—(NOEL) dose of a chemical or biological agent at which there are no biologically or statistically significant effects attributable to treatment

noninsecticidal treatments—gypsy moth treatments that do not involve spraying of insecticides; in this environmental impact statement they include mass trapping, mating disruption, and the sterile insect technique

nontarget organism—any living organism that is not the target of a management practice

Notice of Intent—announcement that preparation of a new national gypsy moth environmental impact statement was beginning, which appeared in the November 12, 1992, *Federal Register* (vol. 57, no. 219, p. 53687-53690)

NPV—acronym for nucleopolyhedrosis virus

nucleopolyhedrosis virus—(NPV) a category of naturally occurring viruses that cause a usually fatal disease, mainly in larvae of moths, butterflies, sawflies, wasps, ants, bees, and others. The nucleopolyhedrosis virus specific to the gypsy moth is the active ingredient in the insecticide Gypchek.

nymph—the larvae of an insect with incomplete metamorphosis that differs chiefly in size and degree of differentiation from the final adult stage

OB—acronym for occlusion bodies

occlusion bodies—(OB) virus particles containing variable numbers of genetic material within one protein envelope

odonates—insects in the order Odonata; dragonflies and damselflies

one-storied stand—a stand of trees that is characterized by the predominance of trees the same size

oral—pertaining to the mouth

organophosphate—a class of insecticides that are toxic to the nervous system

orthopteran—any of insects in the order Orthoptera, which includes grasshoppers, crickets, locusts, and cockroaches

outbreak—a cyclic rise in gypsy moth populations when feeding by caterpillars causes widespread moderate to heavy defoliation

parasite—an organism that lives in, on, or at the expense of another, from which it obtains food, shelter, or other requirements. A parasite is usually smaller than the host and weakens it.

parasitoid—a parasite that eventually kills its host, for example, insects that kill life stages of the gypsy moth

pathogen—an agent, such as a virus or bacterium, that causes disease

pathogenic—causing or capable of causing disease

persistence—the characteristic of an insecticide or a compound to remain in the environment as an effective residue; persistence is related to volatility, chemical stability, and degradation

pH—a measure of acidity and alkalinity on a scale from 0 to 14, on which 7 is neutral, lower numbers are acid, and higher numbers are alkaline; numbers vary by a factor of 10, that is, pH 3 is 10 times more acid than pH 4

pharmacokinetics—the quantitative study of the metabolic processes of absorption, distribution, biotransformation, and elimination of drugs

pheromone—a chemical produced and emitted by an animal as a form of communication with other individuals of the same species, for example, the sex attractant given off by the female gypsy moth to attract males for mating

phytotoxic—poisonous to plants

pituitary-adrenal axis—hormonal interaction between the pituitary and the adrenal glands

planktonic—suspended in the water of seas, lakes, rivers, or other water bodies

polyvinyl chloride—a nontoxic polymer of vinyl chloride

population—a group of gypsy moths that occupy a defined area, are separated to some degree from other groups, and are reproducing

population survey—counting egg masses in the generally infested area to determine if suppression treatments are warranted, or using pheromone traps in the transition area to determine if slow-the-spread treatments are warranted

posttreatment evaluation or survey—a defoliation, egg mass, or larval survey conducted in a treatment area to evaluate treatment effectiveness

predator—an animal that obtains the energy it needs to live and grow by eating animals of other species, for example, some mice are predators of the gypsy moth

probit analysis—an analysis technique that relates doses to measures of standard deviation away from the 50 percent response level, using the cumulative normal distribution

programmatic—broad or general rather than site specific

proposed species—any species of fish, wildlife, or plant that is proposed in the *Federal Register* for listing as a threatened or endangered species under the Endangered Species Act

public involvement—actions taken by the Forest Service and APHIS to involve the various individuals, groups, and organizations who are interested in or may be affected by this environmental impact statement and the decision that may result from it

pupa—the stage of gypsy moth development between the caterpillar and adult moth stages, during which the insect undergoes major structural changes

quarantine—designating an area as generally infested, so as to regulate the movement of articles (such as outdoor household articles, logs, and nursery stock) and prevent artificial spread of gypsy moth life stages to uninfested areas of the United States

racemic mixture—a 50:50 blend of a (+) enantiomer and (–) enantiomer

reference dose—(RfD) the oral dose (mg/kg/day) not likely to be associated with adverse effects over lifetime exposure in the general population, including sensitive subgroups

regeneration—renewal of a tree or stand of trees; restocking of an area

regulatory activities—activities conducted by APHIS and the States to prevent the artificial spread of the gypsy moth from the regulated area to the uninfested area. Activities include inspection and treatment of regulated articles on which the gypsy moth commonly deposits egg masses. See *quarantine*.

reproductive effects—adverse effects on the reproductive system that may result from exposure to a chemical or biological agent. The toxicity of the agent may be directed to the reproductive organs or the related endocrine system. The manifestations of these effects may be noted as alterations in sexual behavior, fertility, pregnancy outcomes, or modifications in other functions dependent on the integrity of the reproductive system.

residue—the quantity of insecticide and its metabolites remaining on and in vegetation, soil, or water

RfD—acronym for reference dose

riparian—pertaining to, or living or situated on, the banks of rivers and streams (Lincoln and Boxshall 1987)

risk—the likelihood that adverse effects will occur; compare *hazard*

risk assessment—evaluation of the likelihood that adverse effects may occur in humans or the environment as a result of exposure to one or more stressors, such as the gypsy moth and treatments

risk characterization—the process of estimating the incidence of a health effect in a human population under the different conditions of exposure described in the exposure assessment

risk reference value—(RRV) a generic term used as an estimate of dose that is not likely to induce adverse health effects in humans under specific conditions of exposure such as duration and route

RRV—acronym for risk reference value

safety factor—a factor used to give a margin of error to the screening index in the Ecological Risk Assessment. Safety factors are selected based on the amount of error likely in estimating toxicological benchmark values or concentrations of a toxicant in the environment.

salvage—cutting and removing dead, dying, or deteriorating trees before they lose their value as timber

scoping—the open process, including public notification and participation, by which an agency identifies significant environmental issues and determines the extent of analysis needed to make an informed decision on a proposed action

screening index—an index used to determine whether a species exposed to a toxic agent is at risk. The screening index is a conservative estimate of species at risk. It is more likely to indicate that a species is at risk when it actually may not be than to miss species that are at risk.

secondary organism—pathogens or insects that attack trees already weakened by defoliation and that sometimes cause death of the trees

sensitive subgroup—a subpopulation that is much more sensitive than the general public to certain agents in the environment

silviculture—the practice of applying treatments to forest stands, to maintain and enhance them for any purpose (Smith 1986). Silvicultural treatments may also be applied to forested areas in urban and suburban areas.

slow the spread—a strategy being pilot tested on a large scale to determine its biological effectiveness and economic efficiency in slowing the gypsy moth's natural spread from areas where it is already established, or is a permanent resident, by keeping low-level populations from increasing

stand—a contiguous group of trees sufficiently uniform in species composition, age, and condition to be distinguishable as a unit (Smith 1986)

stand composition—the variety of vegetation species in a stand

stand growth—increases in wood, dry matter, or biomass within a stand

stand structure—the combination of species, ages, sizes, and numbers of trees that describe a stand

sterile insect technique—a gypsy moth treatment that reduces the chance of fertile female gypsy moths mating with fertile males and producing fertile eggs, by the release of large numbers of (1) male pupae sterilized by radiation, (2) male pupae irradiated but not sterilized, or (3) eggs from mating of irradiated males with nonirradiated females

Stewardship and Stewardship Incentives Programs—cooperative programs between the Forest Service and States, to provide financial and technical assistance for silvicultural planning on non-Federal forested areas for private landowners

strain—a group within a species that differs physiologically rather than in form or structure

strategy—planned actions with specific objectives; the strategies of eradication, suppression, and slow the spread make up the alternatives examined in this environmental impact statement

streptococci—bacteria that may produce disease in people

stressor—an agent, such as an insecticide or the gypsy moth, that causes stress to an ecosystem

subcanopy—the cover of branches and foliage formed collectively by trees and other woody growth that is below the principal canopy

subchronic exposure—exposure studies that can last for different periods of time, but 90 days is the most common duration; the subchronic exposure study is usually performed in two species (rat and dog) by the route of intended use or exposure

subdominant trees—trees with crowns below the general level of the canopy and that receive little or no direct light from above; trees whose crowns make up the subcanopy (Smith 1986)

succession—the natural and gradual replacement of one community of plants by another

sulfhemoglobinemia—the presence of abnormal pigments, other than methemoglobin, in red blood cells

suppression—the strategy of reducing outbreak populations of the gypsy moth in areas where it is already established, or is a permanent resident, to prevent or minimize damage to resources

survey—see *defoliation survey*, *delimiting survey*, *detection survey*, *egg mass survey*, *larval survey*, *National Gypsy Moth Survey*, *population survey*, *posttreatment survey*, and *transition area survey*

susceptible plants—plants with leaves the gypsy moth will eat

systemic effects—effects that require absorption of a toxic agent at an entry point and distribution to a distant site at which effects are produced

technical assistance—any of a whole range of direct and indirect help that USDA provides to Federal and State cooperators, short of providing monetary funds. This assistance includes but is not limited to providing training; providing assistance in preparing environmental documents, work and safety plans, contracts, and monitoring plans; and providing assistance on site during the conduct and evaluation of gypsy moth projects.

technology transfer—disseminating research results and adapting innovations so government and private parties can use them

teratogenic—relating to or causing developmental malformations

thinning from below—the silvicultural technique of removing the subdominant trees in a forest stand, leaving the dominant trees more or less evenly distributed over the stand (Ford-Robinson 1971)

threatened species—a Federal designation for any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range (the Federal list of threatened species is maintained by the Secretary of the Interior)

threshold limit value—an air concentration (milligrams per cubic meter) not likely to cause adverse effects in exposed workers, over a normal period of work

toxicity—the capacity of a poison to cause adverse effects

toxicological benchmark value (or benchmark value)—values determined for any of a number of toxicological tests, such as lethal dose$_{50}$, lethal concentration$_{50}$, no-observed-adverse-effect level, lowest-observed-adverse-effect level

toxicology—a science that deals with poisons and their effect and problems involved (such as clinical, industrial, or legal) (Merriam-Webster 1991)

transition area—the area between the uninfested area and generally infested area; populations are discontinuous, consist mostly of adult male moths, and occasionally other life stages; population outbreaks do not occur, and defoliation is uncommon

transition area survey—monitoring gypsy moths in the transition area to provide data that support the decision to quarantine an area or to take other management action

treatment threshold—the population level reached by an insect pest that indicates treatment is necessary to prevent unacceptable damage to other resources

trichopteran—any of insects in the order Trichoptera, in which the adults are terrestrial and immature life stages are almost exclusively aquatic in freshwater; caddisflies

uncertainty factor—a factor used in deriving the risk reference value and similar values from experimental data. Uncertainty factors are intended to account for variation in sensitivity among people, the uncertainty in extrapolating animal data to humans, and other sources of uncertainty. Common uncertainty factors are 10, 100, and 1000.

understory—the vegetation layer below the canopy of other plants, formed by shade-tolerant trees and low shrubs, grasses, and other herbaceous plants

uninfested area—the area outside the generally infested area and ahead of the transition area; adult male moths are occasionally found, and other life stages are rarely found; no populations are found, and no outbreaks occur

Urban and Community Forestry Program—a cooperative program between the Forest Service and States to provide financial and technical assistance to municipalities, school districts, communities, and nonprofit organizations, for managing trees on non-Federal lands in urban environments

urban forest—forested areas in cities, towns, and communities

USDA—acronym for U.S. Department of Agriculture

U.S. EPA—acronym for U.S. Environmental Protection Agency

vertebrates—animals with a spinal column, such as mammals, fish, birds, amphibians, and reptiles

vulnerability—the likelihood that a tree or plant will die if defoliated

watershed—an area of land with a characteristic drainage network that contributes to the same surface flow

zooplankton—animals that are dependent on movement of water or air for their position or distribution

Chapter 9

References

White pine stripped by gypsy moth caterpillars, circa 1894

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Appendix A

Gypsy Moth Treatments

"Shaw" moth trap with females as bait, circa 1893

Appendix A
Gypsy Moth Treatments
Contents

This appendix describes treatments that are used or are thought to have some value for controlling gypsy moth populations. The treatments vary in effectiveness in different situations. This appendix was prepared in response to public comments that urged an examination of all options for controlling the gypsy moth, including natural control agents.

Treatments in this appendix are divided into two categories. The first contains treatments that are considered to be the most appropriate and most effective in meeting the objectives of gypsy moth suppression, eradication, and slow the spread projects: *Bacillus thuringiensis* var. *kurstaki*, diflubenzuron, gypsy moth nucleopolyhedrosis virus (Gypchek), mass trapping, mating disruption, and the sterile insect technique. Environmental consequences of these treatments were analyzed for this environmental impact statement.

The second category contains treatments that are inappropriate or ineffective in meeting the objectives of suppression, eradication, or slow the spread projects: natural control agents, removing and destroying egg masses, tree trunk bands and barriers, insecticides, and silviculture. Environmental consequences of these treatments were not analyzed for this environmental impact statement. Some of these treatments may be more useful on a single tree in a yard or along a street, rather than in a forest setting or in a large treatment area. Some are undergoing research and may be years away from operational use, if at all; some were never intended for operational use, and some are just ineffective.

Treatments Used in Management Projects

The environmental effects associated with using the insecticides and noninsecticidal treatments described in this section were examined in the Human Health and Ecological Risk Assessments (*app. F* and *G*). Those effects are summarized in *parts A* and *B* of *chapter 4*.

Bacillus thuringiensis var. *kurstaki*

Bacillus thuringiensis, commonly called *B.t.*, is a bacterium that is typically rod-shaped and moves by flagella (whip-like appendages), and forms a resting spore. Unique to this species is the formation of a protein crystal next to the spore at the time of sporulation. *B.t.* occurs naturally in soils worldwide; however, most strains used in commercial insecticide formulations have been isolated from diseased insects (DeLucca and others 1981, Martin and Travers 1989).

B.t. was first isolated from diseased silkworm (*Bombyx mori* [Linnaeus]) caterpillars in 1901 by Ishiwata, who named it *Bacillus sotto*. Berliner isolated another variety of the bacterium in diseased Mediterranean flour moths (*Anagasta kuehniella* [Zeller]) and in 1915 named it *Bacillus thuringiensis* Berliner. Because he recorded the first scientific description of the organism, Berliner is credited with naming it (Beegle and Yamamoto 1992). Berliner's bacterial culture was lost, but Mattes reisolated the bacterium in 1927, from the same host as did Berliner. This isolate was widely distributed and used in most of the early commercial *B.t.* formulations, and is the representative strain for the type species of these crystal-forming bacteria (Reardon and others 1994).

Varieties of *B.t.* number at least 34, some of which are effective against flies (Diptera), caterpillars (Lepidoptera), or beetles (Coleoptera). *B.t.* commercial formulations in use for controlling defoliating forest caterpillars in North America are preparations of the HD-1 strain of *B.t.* variety *kurstaki (B.t.k.)*.

B.t.k. spores and crystals are ingested by the gypsy moth caterpillar along with foliage. The mode of action in susceptible insects is complex, and the details are poorly understood (Reardon and others 1994). Enzymes in the midgut of the caterpillar dissolve the crystals and release the smaller delta-endotoxins, known as insecticidal crystal proteins. The proteins bind to specific receptors on the cellular lining of the midgut and penetrate the cell membrane. Permeability is disrupted causing the cell to absorb water and burst. The result is perforation of the gut and leakage of gut contents, including spores, into the hemolymph (blood). Gut paralysis and sometimes paralysis of the chewing mouthparts occurs, and the insect stops feeding and dies within a few hours or days.

In less susceptible insects the spores germinate and multiply in the hemolymph, causing septicemia—a morbid condition that contributes to death. If gypsy moth caterpillars ingest less than a lethal dose of *B.t.k.*, they stop feeding and their development may become stunted; however, they may recover and resume feeding.

B.t.k. epizootics—widespread *B.t.k.*-induced mortality—have been observed only in very rare instances, and only where caterpillars were in confined environments (Otvos and Vanderveen 1993). Natural epizootics caused by *B.t.k.* have not been observed as a control factor for the gypsy moth (Reardon and others 1994). *B.t.k.* is not expected to infect more than the generation of gypsy moths present when it is applied (Dubois and others 1988).

Use

A number of commercial preparations of *B.t.k* are available for aerial and ground application to gypsy moth populations. The most popular formulations are aqueous flowable suspensions sold under several trade names: Dipel, Foray, and Thuricide. One oil flowable formulation (Condor) and several formulations of nonaqueous emulsifiable suspensions sold under the Dipel label are also available. Label rates for the gypsy moth range from 8 to 40 billion international units (BIU) per acre (20 to 99 BIU/ha), in spray volumes of up to 1.0 gallon per acre (9.34 L/ha) for aerial application, up to 10 gallons per acre (93.4 L/ha) for ground application with mist blowers, and up to 100 gallons per acre (934 L/ha) for ground application using high volume hydraulic sprayers. When the *B.t.k.* formulations are mixed with water before application, a commercial sticking agent is often added to improve adhesion to leaf surfaces and to improve weatherability.

B.t.k. was first used in USDA cooperative suppression projects for the gypsy moth in 1980. Between 1989 and 1994 it was used on more than half of the total acres treated in cooperative suppression projects. During that period more than 5.2 million acres (2.1 million ha) in 10 States were treated with *B.t.k.* (USDA Forest Service 1994d).

B.t.k. is the insecticide of choice for eradicating isolated infestations of the gypsy moth. During the largest eradication project conducted to date, as many as 225,000 acres (91,058 ha) in Oregon were treated with three applications of *B.t.k.* each year between 1985 and 1988. This project demonstrated the effectiveness of *B.t.k.* in eradicating large isolated infestations. Since then, large eradication efforts in excess of 10,000 acres (4,847 ha) have been conducted for the European strain of the gypsy moth in Arkansas, Georgia, Tennessee, Utah, Washington, and Wisconsin. *B.t.k.* has also been used in North Carolina, Oregon, Washington, and British Columbia (Canada) to eradicate the Asian strain of the gypsy moth. *B.t.k.* was used on more than 40 percent of the isolated gypsy moth infestations that were treated between 1967 and 1993 (USDA APHIS 1994). As with suppression projects, the use of *B.t.k.* in eradication projects has increased dramatically in recent years. *B.t.k.* was used in nearly 75 percent of the eradication projects conducted in 1993 (USDA APHIS 1994).

For gypsy moth suppression and eradication, the trend has been towards using higher doses and undiluted (neat) applications of *B.t.k.* Mixing the formulation with water or other adjuvants had been the common practice. The typical application rate used in USDA cooperative suppression projects is one application at 24 BIU per acre (60 BIU/ha), although higher dose rates (30 and 36 BIU per acre [74 and 90 BIU/ha]) and at least one lower dose rate (16 BIU per acre [40 BIU/ha]) were used in 1994 (Schneeberger 1994b). For eradication treatments the typical dose rate is 24 BIU per acre (60 BIU/ha), applied two to three times.

The timing of *B.t.k.* application is generally dictated by foliage and insect development (Dubois

1991). Smaller caterpillars are more susceptible to *B.t.k.* than are larger ones, so application is recommended when the majority of the insects are in the second instar, and is not delayed beyond early third instar. Because *B.t.k.* must be consumed by the caterpillar along with foliage, it should be applied when target tree foliage averages about 45 percent expansion. The timing of *B.t.k.* application is a judgment that considers foliage expansion (typically 45-60 percent leaf expansion in red oak), larval stage (typically 30 percent first instar, 50 percent second instar, and 20 percent third instar), density of the population, and predicted level of defoliation (Reardon and others 1994).

In eradication projects where gypsy moth numbers are so low that egg masses and larvae cannot be located and monitored, phenology models are sometimes used to help predict insect development, so that *B.t.k.* can be applied at the most opportune time. Caged egg masses may also be deployed in treatment areas and monitored for egg hatch, to help determine the best timing for *B.t.k.* application.

Effectiveness

Because *B.t.k.* causes gut paralysis and cessation of feeding by gypsy moth caterpillars, it is well suited as a means to protect tree foliage in the year of treatment. *B.t.k.* has not been particularly reliable, however, in reducing gypsy moth populations into the next year. Data collected on gypsy moth cooperative suppression projects from 1989 and 1990 indicate that treatment with *B.t.k.* met foliage protection objectives set by the States 89 percent of the time, but met population reduction objectives only 60 percent of the time. Greater reductions in gypsy moth populations generally were found with higher dose rates (20 and 24 BIU per acre [49 and 60 BIU/ha]) (Twardus and Machesky 1992). Since these data were examined, higher dose rates and undiluted applications have been more commonly used in cooperative suppression projects, and efficacy may have improved as well.

Many factors affect *B.t.k.* efficacy including the timing of the application with regard to insect and foliage development, weather conditions during and after application, and the quality of the application (such as good pilot skills, properly functioning equipment). Most important is making sure that *B.t.k.* is applied to the foliage on which gypsy moth caterpillars are feeding, and in a sufficient quantity to kill the insects.

B.t.k. has a varying degree of toxicity to larval stages of most moths and butterflies. For example, *B.t.k.* treatments reduce both richness and abundance of native lepidopterans, particularly those species with caterpillars present early in the season when gypsy moth is present (Sample and others 1993b).

Diflubenzuron

Diflubenzuron is a benzoylphenylurea-based insecticide manufactured and sold under the trade name Dimilin. Diflubenzuron belongs to a group of compounds called insect growth regulators. When ingested by gypsy moth caterpillars, diflubenzuron disrupts the formation of a new cuticle (outer skin) during molting. The caterpillar cannot complete the molting process, its body wall ruptures from internal pressure, and the insect dies. Ingestion of diflubenzuron is lethal to any instar of the gypsy moth caterpillar. Diflubenzuron also exhibits some contact insecticidal activity.

Use

Aerial applications of diflubenzuron are commonly used in suppression projects. Both aerial and ground applications are used in eradication projects. Two formulations are available: Dimilin 25W and Dimilin 4L. Dimilin 25W is a wettable powder containing 25 percent diflubenzuron by weight. Dimilin 4L is a liquid containing 40.4 percent diflubenzuron by weight (4 pounds of diflubenzuron per gallon of formulation [480 g/L]). The labels prohibit application directly to water, to areas where surface water is present, or to intertidal areas below the mean high water mark, except under the forest canopy when aerially applied to control forest pests. Beginning in 1994, forestry uses were eliminated from the Dimilin 25W label, leaving Dimilin 4L as the sole formulation for use in gypsy moth projects (Treu 1994). The use of Dimilin 25W in gypsy moth projects will decline as existing supplies (with the forestry use label) are depleted.

The recommended rates for aerial application of diflubenzuron are 0.25-1.00 ounces active ingredient

in 0.5-2.5 gallons spray volume per acre (7-28 g/ 4.67-23.34 L/ha). Significantly more spray volume is required for ground application equipment. No more than two applications per year are allowed, and the yearly total application rate cannot exceed 1.0 ounce active ingredient per acre (70 g/ha), according to label restrictions. Typically diflubenzuron is aerially applied at the rate of 0.5 ounces active ingredient in 0.75-1.00 gallon spray volume per acre (35 g/7-9.34 L/ha); twice in eradication projects and once in suppression projects. Diflubenzuron may be applied in suppression projects at a much lower dosage than the commonly used 0.5 ounces active ingredient per acre (35 g/ha) and still achieve project objectives (McLane 1993). In 1994, gypsy moth cooperative suppression projects in six States applied reduced dose rates of 0.25-0.32 ounces diflubenzuron per acre (18-22 g/ha) (Schneeberger 1994b).

Effectiveness

Diflubenzuron effectively reduces gypsy moth populations and protects foliage, which are both key objectives of suppression projects. Data collected in 1989 and 1990 from areas treated with diflubenzuron in cooperative suppression projects with States show that diflubenzuron had a 98 percent success rate in meeting foliage protection objectives, and an 80 percent success rate for reducing gypsy moth populations below 500 egg masses per acre (1250 egg masses/ha) (Twardus and Machesky 1992). Between 1990 and 1994 diflubenzuron was used on about 40 percent of the total acres treated in cooperative suppression projects (USDA Forest Service 1994d).

Diflubenzuron formulations, which are classified as "restricted use" pesticides because they are toxic to aquatic invertebrate animals, can be sold to and used by certified pesticide applicators only, or by persons under their direct supervision. Diflubenzuron can also adversely affect a wide variety of terrestrial arthropods.

Nucleopolyhedrosis Virus (Gypchek)

The gypsy moth nucleopolyhedrosis virus is one of several kinds of natural agents that are found in eastern North America and infect the gypsy moth (Podgwaite and Campbell 1972). The virus is a member of the genus *Baculovirus* and is unrelated to arthropod-borne viruses and other viruses that infect man (Mazzone and others 1976). The disease caused by the gypsy moth virus is commonly referred to as "wilt disease" because of the limp appearance of infected caterpillars.

The disease can reach outbreak levels naturally, as gypsy moth populations increase. Epizootics caused by the gypsy moth virus are thought to be density dependent and display one or more waves of mortality. The intensity of an epizootic is proportional to larval density and viral inoculum (Doane 1970, Woods and others 1990). Such outbreaks result from increased transmission rates of the virus within and between generations of the gypsy moth, as small caterpillars become infected and die on leaves in the tree crowns. The cadavers disintegrate and the pathogen disperses, infecting other gypsy moth caterpillars.

The virus appears to spread rather easily when egg masses are laid on surfaces that are contaminated with it. Birds, mammals, gypsy moth parasitoids, and invertebrate predators may also play a role in spreading the virus, although they themselves are not affected by it. In dense gypsy moth populations the virus may kill up to 90 percent of the caterpillars and reduce populations to levels that cause only minimal defoliation the next year (Reardon and Podgwaite 1992).

In the late 1950's the U.S. Department of Agriculture (USDA) began investigating the feasibility of developing gypsy moth virus as an alternative to chemical insecticides. In 1978 the virus product Gypchek was registered with the U.S. Environmental Protection Agency (U.S. EPA) as a general use insecticide for ground and aerial application (Reardon and Podgwaite 1992). Gypchek is labeled for use under the supervision of the Forest Service.

Gypchek is specific to the gypsy moth and does not affect other caterpillar species or any other nontarget organisms that might be present in treatment areas (Barber and others 1993). This fact makes Gypchek a desirable insecticide to use where threatened or endangered species might be found or in other environmentally sensitive areas; however, the availability of Gypchek is limited.

Gypchek is produced by the Forest Service and APHIS in quantities sufficient to treat about 20,000

Gypchek contains gypsy moth parts.

acres (8,094 ha) each year. Production involves raising large numbers of gypsy moth caterpillars, inoculating them, and processing the infected caterpillars at the appropriate time. Anywhere from 500 to 1000 infected caterpillars are required to produce enough Gypchek to treat 1 acre with two applications. Widespread operational use of Gypchek hinges on availability and cost (Reardon and Podgwaite 1992).

Gypchek must be ingested by the gypsy moth caterpillar. The rod-shaped virus particles or virions are liberated in the gut of the insect. These virions invade the gut wall and attack the internal organs and tissues, causing infection. The virus multiplies rapidly in cells of the insect and eventually causes breakdown of internal tissue and death. The entire process takes about 10 to 14 days depending on the size of the caterpillar, virus dose, and ambient temperature. First and second instar caterpillars are most susceptible to Gypchek. Dead caterpillars typically hang in an inverted "V" from foliage and branches, and often rupture, releasing polyhedra that can infect other gypsy moths (Reardon and Podgwaite 1992).

Use

Gypchek must be formulated at the mixing and loading site before application. The standard tank mix consists of water (pH 5.0-8.0), an ultraviolet light sunscreen (a lignan sulfate product), a feeding stimulant (molasses), and a sticking agent (to aid adhesion to leaf surfaces). In 1995 a commercially produced and ready-to-use carrier was tested (Carrier 038, Novo Nordisk). The new carrier's ultraviolet protection and spray deposition characteristics are superior to those of the standard tank mix, and the carrier can be applied at lower volumes without sacrificing efficacy. It is also easier to mix and apply (Podgwaite 1995).

Gypchek is aerially applied at the rate of 2×10^{11} to 1×10^{12} occlusion bodies (OB) in 1.0 gallon of spray mixture per acre (4.9×10^{11} to 2.47×10^{12} OB/9.34 L/ha) per application. Ground application may require more spray volume depending on the type of equipment used. Two applications, 3 days apart are recommended. The applications should be timed when gypsy moth caterpillars are in the first and second instars and white oak foliage (if present) is at least 25 percent expanded. Further refinements in dosage and volume are likely.

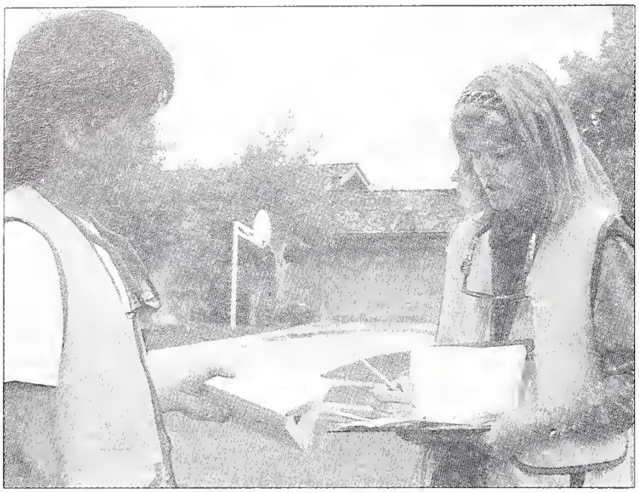
Effectiveness

Gypchek preferably is used against moderate to high gypsy moth populations (300-5000 egg masses per acre [741-12,355 egg masses/ha]). Limited testing in low level populations (less than 100 egg masses per acre [247/ha]) has been encouraging (Podgwaite and others 1993, Reardon and Podgwaite 1992). In 1994 Gypchek was used on 5900 acres (2388 ha) of an environmentally sensitive area near Wilmington, North Carolina, as part of a 140,000-acre (56,000 ha) eradication project for the Asian strain of the gypsy moth. The area will be monitored for 2 years to determine the effectiveness of the Gypchek treatment. As of 1995 no gypsy moth adults have been found in the Gypchek-treated areas.

Mass Trapping

Mass trapping is a commonly used eradication treatment that targets the adult male gypsy moth. This treatment uses the synthetic sex pheromone, disparlure, to attract male moths to traps that have been placed in a grid pattern across the treatment area. The objective of this treatment is to capture male gypsy moths before they have a chance to locate and mate with female moths.

Two types of traps are used depending on the expected number of moths that might be caught. The standard "delta" trap is a small capacity trap about 8



The delta trap has a sticky coating.

inches (20 cm) long, 4 inches (10 cm) high, and triangular in cross section. A tiny plastic strip impregnated with the pheromone is stapled to the inside of the trap. The inside surface of the trap is coated with a sticky substance.

The second type of trap is called the "milk carton" trap because it resembles a half gallon cardboard milk container. This trap is used in areas where large numbers of male moths would quickly overwhelm the sticky surface of the smaller delta trap. As in the delta trap, a small pheromone wick is placed inside the milk carton trap. Unlike the delta trap, however, the milk carton trap contains a 1-inch by 4-inch (2.5 cm x 10 cm) laminated plastic strip that contains the insecticide dichlorvos (2,2 dichloroethenyl dimethyl ester phosphoric acid [DDVP]).

The milk carton trap contains an insecticide strip.

DDVP is registered with the U.S. EPA, manufactured by AMVAC Chemical Corporation (City of Commerce, CA). It is being reregistered (AMVAC 1993). When used in milk carton traps, DDVP is formulated and registered as Vaportape II (Hercon Environmental Company, Emigsville, PA).

Use

Both types of traps are used for detecting and monitoring gypsy moth populations. Delta traps are most commonly used in the uninfested area of the United States to detect and delimit isolated infestations of the gypsy moth. Milk carton traps are more commonly used in areas where large numbers of male moths are likely to be caught. The delta trap primarily has been used for mass trapping; however, milk carton traps might be considered if the numbers of moths are expected to overwhelm the sticky surface in the smaller delta trap (about 15 moths). For mass trapping, delta or milk carton traps are deployed in an intensive grid pattern in an infested area and an adjacent buffer area at the rate of at least 9 traps per acre (23 traps/ha).

Mass trapping is most often used in conjunction with other treatments, commonly insecticides. Between 1967 and 1993, mass trapping was used as a followup treatment on more than 70 percent of the eradication projects conducted. As a primary treatment, mass trapping was used on more than 20 percent of the eradication projects, some as large as 640 acres (259 ha), but the majority were less than 100 acres (40 ha) (USDA APHIS 1994).

Effectiveness

The success of mass trapping depends on the gypsy moth population density in the treatment area, because the tactic depends on luring all the male moths into traps before they can mate with females. The higher the population density, the greater the risk that a male will find (and mate with) a female before being lured into a trap. Therefore, the treatment is best used where there are less than 10 egg masses per acre (25 egg masses/ha) (USDA Forest Service 1989).

Mass trapping is a labor-intensive treatment, especially over large areas. Therefore, it is typically

used on small infestations of less than 100 acres (40.4 ha). It does not affect nontarget organisms, except those (primarily flying insects) that accidentally find their way into the traps.

Gypsy moth pheromone traps are marketed to consumers. There is no evidence, however, that these traps are effective at protecting foliage from gypsy moth feeding or reducing gypsy moth populations within the generally infested area.

Mating Disruption

As with mass trapping, mating disruption relies on the attractive characteristics of the gypsy moth sex pheromone, disparlure. Instead of luring adult male gypsy moths away from females, however, the objective of mating disruption is to saturate the treatment area with enough pheromone sources to confuse the male moths and thereby prevent them from finding and mating with female moths.

Use

Mating disruption can be accomplished either by ground or aerial application of disparlure. The form of disparlure for ground application consists of a laminated polymeric dispenser or tape that is impregnated with the pheromone for slow release into the environment (USDA Forest Service 1989). Because the tape is manually attached to trees in a grid pattern, this method is labor intensive, especially in large treatment areas. Use of the tape was evaluated and found to need additional research before being considered for operational use (Kolodny-Hirsch and others 1990). The tape is no longer produced, but it is still registered with the U.S. EPA and could be made available in the future if requested from the manufacturer (Hercon Environmental Co., Emigsville, PA).

Aerial application of mating disruptants involves the application of small pheromone-impregnated dispensers, of which several types are being tested. One formulation is a commercially available product consisting of small (about 0.1 inch [2.5 mm] long) plastic flakes (USDA Forest Service 1989). The flakes along with a sticking agent are applied by aircraft to the forest canopy and understory vegetation. A drawback of the flakes is that they require special application equipment. To address this limitation other mating disruptants, such as spherical plastic beads, are being evaluated (Leonhardt and others 1992). These can be applied by conventional aircraft spray systems.

Effectiveness

Like mass trapping, the effectiveness of mating disruption depends on the population density of gypsy moths in the treatment and surrounding areas. Mating disruption is best suited for areas that contain less than 10 egg masses per acre (25 egg masses/ha) (USDA Forest Service 1989). In such areas, this treatment is appropriate for use in eradication and slow-the-spread projects.

The use of disparlure as a mating disruptant has received considerable research, which was reviewed by Beroza (1976), Cameron (1979), Plimmer and others (1982), and most recently by Kolodny-Hirsch and Schwalbe (1990). Mating disruption may be used alone or in conjunction with other treatments, primarily insecticides. Only six uses of mating disruption as the primary treatment in eradication projects were recorded between 1967 and 1993 (USDA APHIS 1994). Most of these were conducted after 1989, using the flake formulation for aerial application.

The use of disparlure as a mating disruptant is desirable because the pheromone does not affect nontarget organisms, although once the pheromone has dissipated the plastic dispensers may remain in the environment for some time before disintegrating. Nonetheless, the use of this treatment will probably increase as dose and application techniques are refined.

Sterile Insect Technique

The objective of the sterile insect technique is to reduce the chance that female moths will mate with fertile males, especially when large numbers of sterile males are released in consecutive years. The result is progressively fewer and fewer fertile egg masses being produced, and eventual elimination of the population.

The sterile insect technique is ideally suited for application to the gypsy moth—it has one generation

per year; male moths may mate several times; female moths usually mate only once; and they lay an egg mass that may contain up to 1600 eggs (Reardon and Mastro 1993). The potential of the technique for managing low density and isolated infestations of the gypsy moth was recognized in the mid 1950's. Treatment was not successful, however, until methods were developed for rearing large quantities of quality insects, and quantifying the impact of the releases (Mastro and others 1981).

Use

One of three different approaches is used (Reardon and Mastro 1993): (1) deploying male pupae that were sterilized by irradiation; (2) deploying male pupae that were irradiated but not sterilized (substerile); and (3) broadcasting eggs that had an irradiated male parent (inherited sterility). None of these approaches is without biological and logistical limitations that hamper operational use.

Sterile or Substerile Male Pupae

Initially the sterile insect technique focused on deploying male pupae that had been given a sterilizing dose of radiation. Pilot projects in Maryland, Michigan, and South Carolina between the late 1970's and the mid 1980's demonstrated the efficacy of this technique. Nevertheless, the limited period during which pupae must be released and the need to synchronize rearing of mass quantities of pupae for that release (treated pupae cannot be stockpiled) are obstacles to an operational program (Reardon and Mastro 1993). One major logistical difficulty is the need to repeatedly release the treated insects over the 4-week flight period, because male moths live for only 2 or 3 days.

Deploying substerile insects is the preferred of the two techniques that release male pupae, because (1) the substerile insects suffer less tissue damage and, therefore, are more competitive for females than are the sterile males; (2) the progeny of substerile males and wild females develop in the field and in theory are hardy and in synchrony with the native population; and (3) the suppressive effect on the native population spans at least two life cycles (Knipling 1979, Snow and others 1972).

Inherited Sterility

In induced inherited sterility (or F_1 sterility), males are irradiated but not sterilized before they mate with nonirradiated females in the laboratory. More of the resulting progeny are sterile than in the treated parental generation, and the sex ratio of the progeny is skewed in favor of males (LaChance 1985, North 1975).

Release of F_1 sterile eggs has advantages over the other two techniques: only a single release of treated gypsy moth eggs is required before wild eggs hatch; the production window is wider because eggs can be stockpiled; and the logistics of shipment and release are simpler.

Effectiveness

Between 1988 and 1992 eight isolated infestations of the gypsy moth were treated by releasing F_1 sterile eggs. Results were favorable, but numerous problems were identified (Reardon and Mastro 1993): (1) how to predict when wild eggs will hatch, and how to synchronize release and hatching of the eggs produced in the laboratory; (2) how to reduce mortality that occurs in early F_1 instars; (3) dispersal of F_1 young caterpillars and adult males; and (4) the relative competitiveness of immatures.

When evaluated against low-level gypsy moth populations in Virginia (Reardon 1991), results with substerile pupae, in general, were more favorable than with F_1 sterile eggs. Of the three approaches, the deployment of sterile male pupae is the least desirable. Release of F_1 sterile eggs is preferred; however, the obstacles described are major impediments to more general use of this technique (Reardon and Mastro 1993). The deployment of substerile pupae, in spite of its disadvantages, appears closer to operational use than the other two approaches, although availability of substerile insects is limited.

The sterile insect technique is best suited for use against low density gypsy moth populations, that is, those with less than 10 egg masses per acre (25 egg masses/ha) (USDA Forest Service 1989). To be used successfully, a reasonably accurate measure of the distribution and density of the gypsy moth population is needed so that an adequate number of treated insects can be released.

Treatments Not Used in Management Projects

Because the treatments described in this section were found to be inappropriate for use in gypsy moth management projects, the environmental consequences that could result from using them were not analyzed for this environmental impact statement.

Natural Control Agents

When the gypsy moth was accidentally introduced to this country, few of its natural control agents came with it. This section describes some of those agents, as well as agents native to the United States that can play an important role in regulating gypsy moth populations throughout the generally infested area.

Fungal Pathogens

Insects have diseases caused by microorganisms just as animals and plants do. Several types of fungal diseases can infect the gypsy moth, including *Entomophaga maimaiga* Humber, Shimazu, and Soper. This fungus, commonly found in Japan (Soper and others 1988), was brought to the United States in the early 1900's and released, but was never recovered. *E. maimaiga* is known to infect only the gypsy moth and other closely related caterpillars (Reardon and Hajek 1993), and poses no known health risks to people or pets. It is a virulent pathogen of the gypsy moth and is known to cause extensive epizootics in Japan (Shimazu and Soper 1986).

In 1989, epizootics of *E. maimaiga* in gypsy moth were reported in the northeastern United States, representing the first reported occurrence of this fungus in North American gypsy moth populations (Andreadis and Weseloh 1990, Hajek and others 1990). Unlike the gypsy moth nucleopolyhedrosis virus, which is associated with high gypsy moth population densities, the fungus appears capable of causing dramatic mortality to middle and late stage gypsy moth caterpillars at densities of about 70 egg masses per acre (Shimazu and Soper 1986). Since the fungus tends to cause mortality earlier than the virus, tree defoliation may not be as severe.

The resting spore of the fungus overwinters on the bark of trees, in leaf litter, and in soil (Shimazu and others 1987). In spring the resting spore germinates and produces a single infecting spore called a conidium, which is released into the environment and may be carried in the air. Once on a susceptible caterpillar, the conidium germinates, penetrates the insect's skin, and in 7 to 10 days spreads throughout the caterpillar and kills it. Infected dying caterpillars typically hang with head down, in a stretched out position on the stems of infested trees (Hajek and Roberts 1992).

When favorable conditions with high humidity occur, the fungus grows out of the caterpillar through the insect's skin, and produces and releases more conidia (infecting spores), which may subsequently infect other caterpillars. This secondary infection cycle is a major contributor to the dramatic epizootics observed in gypsy moth populations. When conditions are unfavorable or as the end of the feeding period of gypsy moth caterpillars approaches, *E. maimaiga* begins to produce resting spores inside the dead caterpillars (Hajek and Soper 1992). The dead caterpillars slowly disintegrate, scattering the resting spores into the environment, with most accumulating in the soil.

Since 1989 the fungus has spread across a large portion of the generally infested area, apparently by spore movement on the wind and intentional introduction (Elkinton and others 1991). Epizootics of *E. maimaiga* have occurred in New England and some Middle Atlantic States, and its distribution continues to expand into areas more recently colonized by the gypsy moth. The fungus is so widespread in parts of Virginia and Michigan that it is difficult to determine whether the presence of the fungus at an individual location resulted from natural migration of the pathogen from where it is established or spread from a release (inoculation) site (Reardon and Hajek 1995).

It is not clear why the fungus has suddenly appeared almost 80 years after its initial introduction into the United States. Among the hypotheses offered, the most plausible may be these two: (1) a more aggressive strain of *E. maimaiga* arose through natural selection some time after its release in 1910-1911; or (2) the fungus was more recently introduced accidentally (Hajek and others 1995).

Numerous constraints limit the development of *E. maimaiga* for use as an insecticide (Reardon and Hajek 1993). Fungi are often short-lived in storage, they are relatively expensive to produce, and foliar applications of fungi are sensitive to heat, humidity, sunlight, and rainfall. Formulation and application of dried fungal preparations also present unique challenges of getting them to adhere to leaf surfaces and protecting them from adverse environmental conditions.

The release of *E. maimaiga* into uninfested areas on a large scale is problematic as well. Relocation of soil containing resting spores requires a permit from the USDA Animal and Plant Health Inspection Service and additional precautions to ensure that plant pathogens, such as *Armillaria mellea*, and arthropod pests are not unintentionally spread as well (Reardon and Hajek 1993).

E. maimaiga may eventually contribute to the long-term control of the gypsy moth; however, studies have only begun to identify the information on the host-pathogen interactions that are vital to developing the fungus for effective biological control of the gypsy moth. Additional research is needed in field ecology, population dynamics, and the biology of *E. maimaiga* before it can be developed and field tested as a biological insecticide (Reardon and Hajek 1993).

Parasitoids

Parasitoids live in or on another organism and benefit from the relationship at a cost to the host, which often dies.

Two approaches have been used to introduce parasitoids into the gypsy moth population in North America: classic biological control and augmentation. The discovery, importation, release, and attempted establishment of exotic natural enemies of the gypsy moth are all part of classic biological control (Reardon 1981). Manipulation to initiate or increase effective biological control by established parasites is termed augmentation (Blumenthal and others 1981).

In general, parasitoids together with other natural enemies (predators and pathogens) help regulate populations of the European strain of the gypsy moth by reducing their numbers, but most researchers do not believe that they play a major role in regulating gypsy moth populations (Elkinton and Liebhold 1990). The rate of parasitism from a particular parasite species varies from site to site and from year to year, depending on such factors as the number of gypsy moth caterpillars, the number of alternative hosts, and the weather. Parasitoids are thought to help maintain low density populations of the European strain, but do not prevent the buildup of already increasing populations (Campbell 1974b). The tachinid flies *Compsilura concinnata* (Meigen) and *Parasetigena silvestris* (Robineau-Desvoidy) may play some role in suppressing incipient outbreak populations, but such population decline may go unnoticed (Elkinton and Liebhold 1990).

Foreign exploration for gypsy moth parasitoids was started in 1904 by the State of Massachusetts and the then Federal Bureau of Entomology, and continues today by the USDA. Over 250,000 parasitoids of more than 85 species have been sent to the United States from collection areas around the world. Ten of these imported species have been released and have become established in the United States (Elkinton and Liebhold 1990). Also, several parasitoids native to the United States have become opportunistic parasitoids of the gypsy moth, that is, when gypsy moths are available. A summary of the major established gypsy moth parasitoids follows.

The principal egg parasitoids in North America are *Ooencyrtus kuvanae* (Howard) (Hymenoptera: Encyrtidae) and, to a much lesser degree, *Anastatus disparis* Ruschka (Hymenoptera: Eupelmidae). *O. kuvanae* typically attacks 10 to 40 percent of the eggs in an egg mass (Brown 1984). The rate of parasitism is greater in smaller egg masses typical of high density declining gypsy moth populations (Bellinger and others 1988, Brown and Cameron 1979).

Cotesia (=*Apanteles*) *melanoscelus* (Ratzeburg) is a small braconid wasp that parasitizes early instar gypsy moth caterpillars, and has two generations per year. Hyperparasitoids, which prey on other parasitoids, severely reduce the numbers of *C. melanoscelus* that overwinter (Weseloh 1983). Also limiting the wasp's effectiveness is the poor synchronization of the parasitoid's second generation with its host (Weseloh 1976). Higher parasitism rates, however, have been reported when early gypsy moth instars are prolonged, such as when they ingest sublethal doses of *B.t.k.* (Weseloh and Andreadis 1982).

Parasetigena silvestris (Diptera: Tachinidae) is a tachinid fly that lays an egg on the outer skin of the gypsy moth caterpillar, and has a single generation per year. The fly is most active during daylight, and often causes more mortality than any other parasitoid. Peak parasitism tends to occur after gypsy moth populations decline from high densities (Elkinton and Liebhold 1990). In Europe parasitism by *P. silvestris* sometimes exceeds 95 percent (Bogenschutz and others 1989).

The tachinid fly *Blepharipa pratensis* (Meigen) (Diptera: Tachinidae) is a major source of mortality in intermediate density gypsy moth populations (Ticehurst and others 1978). It lays small eggs on foliage being fed upon by gypsy moth caterpillars. The eggs hatch after being ingested by caterpillars.

Brachymeria intermedia (Nees) (Hymenoptera: Chalcididae) is a small wasp that attacks gypsy moth pupae and other hosts. It was introduced in 1908 but was not recovered until 1942. By 1971 it was abundant (Doane 1971). The parasitoid was observed causing high mortality of gypsy moths in Pennsylvania (Ticehurst and others 1978) and on Cape Cod (Elkinton and others 1989). *B. intermedia* tends to be scarce in low density gypsy moth populations and, therefore, probably does not contribute substantially to maintaining gypsy moth populations at innocuous levels (Elkinton and Liebhold 1990).

Lastly, the tachinid fly *Compsilura concinnata* (Diptera: Tachinidae) has a wide host range including the gypsy moth. Because this insect has many hosts and several generations per year, it can remain abundant when gypsy moth populations are low. It often causes higher mortality than other parasitoids in low density gypsy moth populations (Elkinton and Liebhold 1990).

Augmentation of these established parasitoids has not proven to be an effective means to control gypsy moth populations (Blumenthal and others 1981). Classic biological control efforts continue to be an important avenue for study, however, because the search for and importation of gypsy-moth-specific natural enemies from Europe and Asia remains promising.

Predators

Many species of animals eat the gypsy moth and other forest-defoliating insects. Some predators feed on only one life stage of the gypsy moth, while others consume two or more life stages (Smith 1985). Predation can help to maintain sparse, stable gypsy moth populations indefinitely; however, periods of low predatory pressure do not necessarily lead to an outbreak. Once an outbreak starts, as well as during subsequent outbreak decline, predation has no significant effect on population densities (Smith and Lautenschlager 1981).

The gypsy moth predator community is complex and includes about 50 species of birds and 20 species of mammals, along with some amphibians, reptiles, fish, insects, and spiders. Only a few of these predators are known to affect gypsy moth population dynamics (Elkinton and Liebhold 1990, Smith and Lautenschlager 1981). The predators are all opportunistic feeders, which means that their taste for the gypsy moth depends upon the scarcity of preferred foods. For example, robins may eat gypsy moth caterpillars when earthworms become scarce.

Bess and others (1947) were the first to suggest that predation by small mammals was important to gypsy moth population dynamics in North America. Vertebrate predators, especially the white-footed mouse (*Peromyscus leucopus*), are major sources of late-larval and pupal mortality in low density gypsy moth populations (Campbell and Sloan 1977b,c, Campbell and others 1977), but not at higher gypsy moth densities (Campbell and others 1975, 1977). Recent findings support the role that small mammals play in helping to maintain low density gypsy moth populations (Elkinton and Liebhold 1990).

The earliest study of predation by birds was conducted by Forbush and Fernald (1896). They listed 38 bird species seen eating one or more life stages of the gypsy moth. Recent studies of bird predation, however, tend to show that gypsy moth is not a major food item of most species (Cooper 1988). In feeding preference studies birds were shown to prefer hairless caterpillars over gypsy moth caterpillars (Whelan and others 1989). Predation by birds is frequently cited in European literature as an important influence on gypsy moth population dynamics, but few studies exist to support that claim (Elkinton and Liebhold 1990).

The impact of invertebrate predators, such as ground beetles and ants, on gypsy moth pupae is less than that of vertebrates (Campbell and Sloan 1976, Elkinton and others 1989). Most predation by invertebrates occurs in leaf litter; little predation occurs in the tree canopy (Weseloh 1988). Adult and immature stages of *Calosoma sycophanta* (L.), a large predaceous ground beetle introduced into North America from Europe, feed on gypsy moth caterpillars and pupae. *C. sycophanta* populations increase in response to high density gypsy moth populations and tend to lag 1 to 3 years behind the onset of gypsy moth outbreaks (Weseloh 1985a, Smith and Lautenschlager 1978). The impact of *C. sycophanta* on low density gypsy moth populations is thought to be minor (Weseloh 1985b, Smith and Lautenschlager 1978).

Predators can be encouraged by maintaining habitat diversity when managing or enhancing the appearance of a forest, woodlot, or backyard. For instance, people unknowingly destroy good habitat for predators by removing brush in an effort to "clean up" yards and woodlots. Such cleanup efforts significantly decrease the survival of small mammals and increase the survival of gypsy moths.

To increase predator effectiveness, forest and woodlot maintenance should be compatible with the diverse needs of predators. For example, leaving dead "snag" trees will increase populations of cavity-nesting birds, such as woodpeckers, that eat gypsy moths. Placing nesting boxes to supplement snags may also encourage cavity-nesting birds. Leaving piles of brush may encourage populations of small mammals, such as mice and shrews, that eat gypsy moths.

With regard to the Asian strain of the gypsy moth, birds probably play an important predator role. The importance and impact of small mammals is not known. If caterpillars and pupae of the Asian strain remain in the trees most of the time (unlike those of the European strain), small mammal predators that forage on the ground are not likely to be as important as they are for the European strain. Research on the Asian strain will help provide this information.

Nematodes

Nematodes that attack insects could be used in residential areas to protect individual trees from defoliation. They have provided control of several ground-dwelling and tree-boring insect species, although results against defoliators such as the gypsy moth are inconsistent (Gaugler 1981, Kaya and Reardon 1982, Kaya and others 1981). Depending on the species, nematodes may actively search out their hosts and enter their body openings. A bacterium associated with the nematode kills the host. In one study, two species of commercially available nematodes, *Steinernema carpocapsae* Weiser and *S. feltiae* Filipjev, were applied to cloth-lined burlap and plastic bands around tree boles to infect resting gypsy moth caterpillars. The results were highly variable between trees, primarily due to the nematode's need for a humid environment (Reardon and others 1986). Nematodes may have potential for use against the gypsy moth. Research continues.

Removing and Destroying Egg Masses

One of the first gypsy moth treatments was removing and destroying egg masses. Broad application of this technique to control the gypsy moth reached its zenith in the 1930's when Civilian Conservation Corps workers were employed in New England during the fall, winter, and early spring to seek out and destroy egg masses in towns and woodlands. The technique is labor- and time-intensive and, for large areas, is impractical. Also, experience has shown that in a forested area, many more egg masses are present than are actually seen and disposed of. The technique may be helpful in urban or suburban areas on accessible trees or ornamental plantings. Careful searching, removal, and destruction of egg masses may help reduce the potential for damage due to the gypsy moth in these situations.

Removal and destruction of egg masses, while not an effective or practical means for reducing damage caused by gypsy moth outbreaks in the generally infested area, is commonly used as a regulatory treatment. Safe and effective materials for destroying egg masses are of interest to regulatory officials in helping to prevent the interstate spread of viable egg masses and to spot treat egg masses of the European and Asian gypsy moth strains that arrive in the United States aboard ships or on cargo.

Removing egg masses is done as a regulatory treatment.

Since 1976 a number of surfactants, oils, detergents, and insecticides have been evaluated for use in quarantines, as well as in community action programs. A soybean oil preparation, Golden Natur'l Spray Oil, has been registered for spot treating egg masses, using a small hand sprayer or spray bottle. Egg masses can be treated anytime, but treatments applied in fall using a 50 percent concentration (regulatory officials) and a 25 percent concentration (homeowners and arborists) are nearly 100 percent effective in killing gypsy moth eggs (Webb and others 1994).

Tree Trunk Bands and Barriers

As with removal and destruction of egg masses, removal and destruction of gypsy moth caterpillars may be useful in localized urban and suburban situations where small numbers of trees are at risk. The habit of caterpillars to move down from the crown and rest in protected areas during the day can be used to collect them. Bands, commonly of burlap, are placed around the trunks of susceptible trees to serve as resting areas for caterpillars seeking shelter. The bands must be checked each day so caterpillars can be scraped off and killed. During an outbreak, however, caterpillars may remain in the canopy and feed night and day, thus reducing the effectiveness of this method. Except as a survey tool, use of this technique in a forest situation is impractical.

A variety of trunk barriers is commercially available. Barriers that include a sticky surface have been shown to be the most effective (Webb and Boyd 1983). An effective sticky barrier can be made by wrapping the trunk of a susceptible tree with duct tape (to protect the bark and provide a smooth surface) and applying a thin layer of Tanglefoot. Gaps between the tape and the tree surface can be filled with fabric, polyester pillow stuffing, or any other suitable material. Trunk barriers should be in place just before gypsy moth as eggs hatch, usually in March or April, depending on location.

While properly maintained sticky trunk barriers are extremely effective at preventing caterpillars from climbing trees, they have no effect on caterpillars that are already in the canopy. For this reason, the impact of the barriers is usually limited to a 20-30 percent

Sticky barrier bands are the most effective trunk barriers that are commercially available.

reduction in caterpillar numbers in treated trees over the season (Thorpe and Ridgway 1994, Thorpe and others 1993). The degree of foliage protection that can be expected is even more variable, but also usually averages 20-30 percent. Therefore, while trunk barriers will provide some benefit, they should never be relied on to protect foliage.

Insecticides

A number of insecticides other than *B.t.k,* diflubenzuron, and Gypchek are registered by the U.S. EPA for gypsy moth control. Acephate, carbaryl, and trichlorfon were used in the gypsy moth management program in the past. Some insecticides are registered either for gypsy moth control or for control of pests where gypsy moth is likely to be present, for example, in areas with susceptible shade or ornamental trees. Insecticides such as acephate, malathion, carbaryl, methoxychlor, spectracide, and diazinon may be available for use by homeowners. All of these insecticides were excluded from this environmental impact statement because they affect a wider range of nontarget organisms than do *B.t.k.*, diflubenzuron, and Gypchek.

Acephate was evaluated for protection of individual trees by injection into the tree through the Mauget Systemic Unit and ACECAPS. Both of these methods provide a portable, closed system that minimizes loss of insecticide into the environment. ACECAPS implanted into trees reduced the gypsy moth population significantly and protected foliage during the year of treatment (Webb and others 1988), but year-to-year use on the same tree was not recommended (Reardon and Webb 1990). Also, since some internal and external wound response was evident on most of the oak species evaluated, these injection techniques are not recommended for use in residential areas.

Silviculture

Silviculture is the practice of applying treatments to forest stands to maintain and enhance their utility for any purpose (Smith 1986). Silvicultural guidelines have been designed to minimize the effects of the gypsy moth on forest stands and trees, and are being evaluated for effectiveness. The guidelines recommend treatments to minimize gypsy moth impacts before, during, and after outbreaks (Gottschalk 1993).

The greatest range of silvicultural options for gypsy moth control is before the insect becomes established in an area. Before outbreaks, silvicultural treatments may reduce stand susceptibility and vulnerability by increasing stand and tree vigor, removing trees most likely to die, reducing gypsy moth habitat, reducing preferred gypsy moth food sources, improving predator and parasite habitats, and regenerating stands that are close to maturity or understocked. In urban and suburban areas, silvicultural considerations include planting trees that are less susceptible to the gypsy moth. These silvicultural treatments should be conducted at least 2 years before the gypsy moth arrives in an area, to allow the remaining or newly planted trees to recover from the stress of treatment.

Once the gypsy moth becomes established, or outbreaks occur or are imminent, silvicultural options are reduced. During gypsy moth outbreaks, silvicultural guidelines help prioritize stands that could receive gypsy moth treatments, and help determine if stands should be regenerated.

After gypsy moth outbreaks, silvicultural treatments focus on the efficient salvage of dead trees and the regeneration of stands that had heavy mortality or are close to maturity.

One advantage of silvicultural treatments is that action can be taken long before the gypsy moth arrives. It could take years, however, to treat large areas because other resource considerations may limit the amount of cutting in an area. Silvicultural treatments cannot be used in some special areas, such as wilderness.

Appendix B

Gypsy Moth Program

Massachusetts Experiment Station and Insectary, 1895

Appendix B
Gypsy Moth Program
Contents

The U.S. Department of Agriculture (USDA) has played a role in gypsy moth management since 1906, when Connecticut and Massachusetts first requested aid from the Federal government. Since then, gypsy moth related work has evolved into a comprehensive national effort involving several USDA agencies: Forest Service; Animal and Plant Health Inspection Service (APHIS); Agriculture Research Service (ARS); and Cooperative State Research, Education, and Extension Service (CSREES).

The USDA assigned responsibilities to these agencies, defined their roles to avoid duplication, and established the following gypsy moth policy (USDA 1990a):

- Provide a comprehensive program of gypsy moth management activities coordinated by a designated lead agency
- Protect Federal lands and assist States in protecting non-Federal lands from gypsy moth damage
- Prevent or reduce the artificial long-range spread of the gypsy moth
- Develop effective gypsy moth eradication and suppression measures
- Conduct gypsy moth surveys and population assessments in cooperation with the States
- Plan and conduct fundamental and applied research on the gypsy moth in partnership with the agricultural experiment stations and other cooperators to support Federal and State extension, regulatory, and action programs
- Coordinate research planning and cooperation within the USDA and with other Federal, State, and private agencies
- Emphasize research deemed necessary by Federal and State cooperators from the research, extension, and action communities
- Follow an integrated pest management approach (USDA 1993b).

The Forest Service serves as the lead agency for USDA gypsy moth activities. It carries out its lead role through the USDA Gypsy Moth Working Group, in which APHIS, ARS, and CSREES participate.

These USDA agencies implement departmental gypsy moth policy by conducting a number of activities: prevention, survey and detection, public involvement and notification, treatment projects, monitoring and evaluation, planning assistance for forests and trees, methods development, technology transfer, research, and public information and education (*fig. B-1*). Of these activities, treatment projects are within the scope of this environmental impact statement.

This appendix describes USDA's gypsy moth program and how it is linked to other programs. Activities are presented roughly in the order they occur, although some are ongoing.

Prevention

Port-of-Entry Activities

The APHIS port-of-entry program involves ship and port inspections that are carried out to prevent introductions of foreign pests. Carriers and cargo arriving at U.S. ports of entry are inspected for the presence of exotic pests. Ships that visit ports in the Russian Far East during the time gypsy moths are laying eggs are targeted for special inspections, if they arrive in the United States during the period when the eggs are hatching. Cargo from areas of Europe and Russia that are having gypsy moth outbreaks may be reinspected upon arrival and is treated if gypsy moth life stages are found.

In 1993 APHIS and the Forest Service conducted surveys for the Asian strain of the gypsy moth at several ports in the Russian Far East, in a cooperative project with Russian counterpart agencies—the Plant Quarantine Inspection Service and the Federal Forest Service of Russia. Trapping was conducted in three major ports—Vladivostok, Vostochnyy, and Nakhodka—and the surrounding forests. Contacts were made with Germany in 1994, to increase surveillance around infested areas there.

Activities in the gypsy moth program

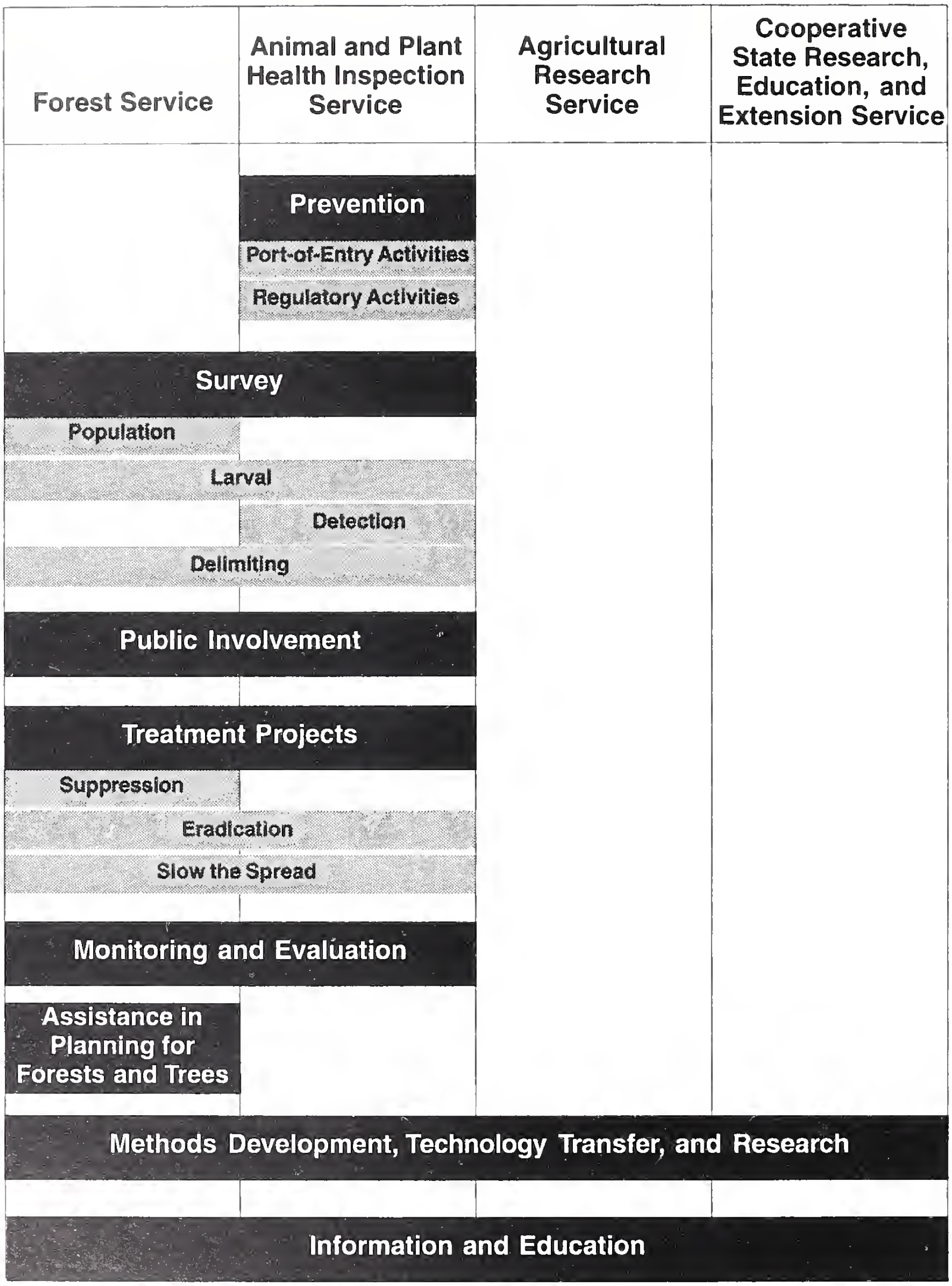


Figure B-1. The gypsy moth program is a coordinated effort administered by four USDA agencies—Forest Service; Animal and Plant Health Inspection Service; Agricultural Research Service; and Cooperative State Research, Education, and Extension Service.

Pheromone traps, black light traps, sticky traps, and egg mass and larval surveys were used to gather baseline data on moth populations for use in monitoring fluctuations in population levels. This information will help APHIS formulate exclusion guidelines.

Regulatory Activities

The Secretary of Agriculture is authorized to quarantine States with areas that are generally infested by the gypsy moth, to prevent its artificial spread. The Administrator of APHIS lists the States or portions of States that are subject to regulatory activities because they are infested, close to an infestation, or because they are necessary to enforce a quarantine. In 1994 the States of Connecticut, Delaware, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, and the District of Columbia were either fully or partially regulated.

Gypsy moth regulatory activities are conducted to prevent, retard, delay, or minimize interstate artificial spread of the gypsy moth to uninfested areas (USDA APHIS 1990). Regulated articles, such as nursery stock, trees without roots, outdoor household articles, mobile homes, logs, firewood, and pulpwood, are inspected for the presence of gypsy moth life stages—usually egg masses. If life stages are found, the articles are treated before their movement is permitted. Treatments include removing egg masses, spraying them with a formulation of soybean oil, and fumigation. Inspection and treatment of regulated articles is a cooperative effort involving APHIS and the States. Included as part of regulatory activities is a public information campaign targeting the public and commercial movers.

Compliance agreements are used to control commercial shipment of wood, nursery stock, logs, and pulpwood out of regulated areas.

The USDA does not consider an area generally infested when (1) an eradication program is being conducted in the area, and (2) delimiting surveys catch an average of less than 10 moths per trap and show that the eradication program is reducing the gypsy moth population. Infested areas may be temporarily designated as generally infested and regulated, until the above criteria can be met.

Survey

Surveys are conducted to monitor gypsy moth populations and to determine the extent of infestations.

Population Survey

Surveys to determine the size and vigor of populations are conducted within the generally infested and transition areas. Within the generally infested area, the purpose of tracking gypsy moth populations is to determine if suppression activities are warranted. Populations are tracked within the transition area to determine if slow-the-spread activities are needed.

The Forest Service is directly responsible for conducting surveys on the National Forests, on other Federal lands in cooperation with Federal agencies, and on non-Federal lands in cooperation with States (USDA 1989). In the generally infested area surveys are accomplished primarily by visual examination for egg masses. In the transition area surveys are accomplished primarily by trapping male moths. Specially designed traps are baited with a manufactured version of the pheromone produced by the female gypsy moth to attract male moths.

Larval Survey

Larval surveys may be conducted to assess development of gypsy moth caterpillars. This information is used to determine the proper timing for insecticide applications, and may also be necessary for research purposes. Larval surveys use tar paper, burlap, or a similar material placed around the trunks of trees to create hiding places for caterpillars so they can be captured (USDA APHIS 1990).


Larval surveys may use burlap bands.

Detection Survey

Both APHIS and the Forest Service conduct detection surveys.

Animal and Plant Health Inspection Service

One purpose of a detection survey is to locate isolated infestations of the gypsy moth. APHIS is responsible for conducting detection surveys for the European strain of the gypsy moth, through appropriate agencies, on all lands outside the generally infested area (USDA 1989). APHIS also is responsible for conducting detection surveys for the Asian strain. State agencies cooperate on non-Federal lands, and other Federal agencies cooperate on Federal lands. APHIS detection surveys are conducted only in areas with tree species suitable to the gypsy moth or that have potential for introduction of the gypsy moth (USDA APHIS 1990). Surveys conducted by APHIS in U.S. ports of entry are a form of detection survey.

Detection surveys are conducted from late spring to late summer, to cover the period from when adult males first emerge to when their flight period ends. Traps baited with pheromone are placed in a grid pattern. Trapping density and frequency are based on guidelines contained in the National Survey Plan (USDA APHIS 1990). The National Gypsy Moth Survey is a minimal survey, which detects infestations before expansive land areas have to be treated.

Forest Service

The Forest Service conducts detection surveys to find insect pests or the damage they cause. For example, gypsy moth defoliation surveys, conducted from the air or the ground, are commonly used to locate outbreaks in the generally infested area. Detection surveys are also used to monitor the success or effectiveness of suppression projects.

Delimiting Survey

When adult male gypsy moths are caught through the procedures established in the National Survey Plan, delimiting surveys may be used to confirm the presence of established populations, their approximate size, and their geographic extent. Pheromone-baited traps are used, but at a much higher density than in detection surveys. APHIS and the Forest Service conduct delimiting surveys in cooperation with States and Federal agencies. APHIS and the Forest Service use the trapping results in planning eradication projects. The Forest Service uses the results in planning projects that are part of the Slow-the-Spread Pilot Project.

Public Involvement and Notification

The Forest Service, APHIS, and the State and Federal agencies that cooperate with them actively seek public participation and involvement at the local level, for planned treatment projects. The purpose of this public involvement is to . . .


Public support results in a better program.

- Explain the project and the need for it
- Discuss the consequences, if any, of the proposed project
- Solicit public input to identify local issues
- Stimulate discussion of alternative measures and their consequences.

In addition, before suppression, eradication, or slow-the-spread projects are carried out, public involvement and notification is started and may include these activities:

- Providing notice of involvement activities in local newspapers, newsletters, and other media
- Making the environmental impact statement, environmental assessments, and related documents available to agencies, groups, and individuals who may be interested in or affected by the proposed action
- Announcing treatment dates to make it possible for those with concerns about insecticide application to avoid exposure
- Ensuring that cultural and social considerations are included while planning and conducting public involvement and notification activities.

Treatment Projects

Treatment projects are conducted under the strategies of suppression, eradication, and slow the spread. Each strategy has a different objective for gypsy moth management, and is used in a different part of the country, depending on local gypsy moth populations. Treatment projects are implemented on a case-by-case basis.

Cooperators must contact the U.S. Fish and Wildlife Service for compliance with the Endangered Species Act and must contact State agencies responsible for State Heritage Programs or State endangered or threatened species lists early in the planning process for treatment projects.

In addition, contact with lepidopterists, spelunkers, and bat experts familiar with the local area and conditions is recommended to increase the likelihood that all planned actions conserve all known habitats and species protected by Federal or State law.

Suppression

Suppression projects are conducted to protect the environment from the damaging effects of the gypsy moth within the generally infested area. No attempt is made to treat all outbreak populations within a given area or State. Decisions to suppress gypsy moth populations are made annually by the responsible land manager on Federal lands, and by the responsible State official on State and private lands. Surveys and evaluations are completed by Forest Service forest pest management specialists on Federal lands; and by State forest pest management specialists on State and private lands, through the Cooperative Forest Health Program. Site-specific environmental analyses are prepared by Federal resource managers on Federal lands; by forest supervisors on National Forests; and by Forest Service regional foresters or the Northeastern Area director on State and private lands. Gypsy moth populations are suppressed directly by the Forest Service on National Forest System lands, in cooperation with State agencies on non-Federal lands, and in cooperation with responsible officials on other Federal lands.

To be considered by the U.S. Department of Agriculture for funding, proposed suppression projects must meet these criteria (USDA Forest Service 1990b):

- Show strong potential for effective control
- Be supported by a biological evaluation that substantiates the need for the project
- Be environmentally acceptable, having met requirements of the National Environmental Policy Act (CEQ 1992)
- Be supported by economic analysis, and a project work and safety plan.

Eradication

Eradication projects are conducted to eliminate isolated infestations of the gypsy moth that have spread artificially into the uninfested area, or to eliminate the Asian strain of the gypsy moth in the generally infested area when the location, extent, and time of the introduction are known.

Annual eradication projects are conducted in cooperation with Federal and State agencies and are based on the availability of Federal funds, a mutually agreed upon plan of work, and the results of site-specific environmental analyses conducted in accordance with the National Environmental Policy Act (CEQ 1992).

A memorandum of understanding between the Forest Service and APHIS identifies the roles and responsibilities for eradicating the European strain of the gypsy moth (USDA 1989). APHIS is responsible for conducting eradication projects on non-Federal lands when infestations cover 640 or fewer acres (259 ha) and are not next to Federal land. The Forest Service conducts eradication on National Forest System lands, and cooperates with other agencies in projects on other Federal lands. The Forest Service also conducts eradication projects in cooperation with States on non-Federal land that is next to Federal land, and on non-Federal land when infestations cover more than 640 contiguous acres.

APHIS is responsible for eradicating the Asian strain of the gypsy moth regardless of the infestation's location or size because the Asian strain is considered to be an exotic pest.

Slow the Spread

Traditionally, little effort has been placed on managing gypsy moth populations in the transition area. The slow-the-spread strategy developed for this area has the objective of slowing the expansion of the generally infested area. Slow the spread involves conducting intensive surveys with pheromone-baited traps to detect low-level gypsy moth populations in the transition area. Populations that meet specific criteria (based on counts of male moths, or other life stages, or both) are treated (USDA 1993a). A 5-year pilot project was started in Michigan, North Carolina, Virginia, and West Virginia in 1992 to evaluate the slow-the-spread strategy.

Monitoring and Evaluation

The Forest Service and APHIS monitor some treatment projects, particularly those in environmentally sensitive areas, to see that they are carried out as prescribed and to determine whether effects on the environment are those expected. The Forest Service and APHIS also conduct evaluations of gypsy moth infestations in treated areas to determine whether projects were effective.

Assistance in Planning for Forests and Trees

The Stewardship Program and the Stewardship Incentives Program, led by the Forest Service in cooperation with the States, provide technical and financial assistance for forest management planning. These programs provide an opportunity to assess potential damage from the gypsy moth and to develop contingency management plans.

The Urban and Community Forestry Program, also led by the Forest Service, encourages opportunities for replacing susceptible tree species with resistant or less susceptible species (USDA Forest Service 1993d). In keeping with the Forest Service's philosophy of ecosystem management, long range tree care plans and continued inventories need

to emphasize species that are less preferred by gypsy moth caterpillars. Financial and technical assistance are available to municipalities, school districts, communities, and nonprofit organizations (but not individual landowners) for managing individual trees or groups of trees on non-Federal lands in urban environments, with the gypsy moth as a major management consideration.

Methods Development, Technology Transfer, and Research

The Forest Service, APHIS, and ARS develop new or improved methods of dealing with the gypsy moth. The Forest Service and APHIS also implement new technology required to support gypsy moth control activities (USDA 1990a).

Within the USDA, gypsy moth research is conducted as part of a broad research program administered by the Forest Service, APHIS, ARS, and CSREES. A Gypsy Moth Research and Development Coordinating Group representing these agencies monitors the progress of gypsy moth related programs and findings, keeps the agencies informed of progress in research and methods development, identifies relevant issues and concerns, and sets priorities for research and methods development (USDA 1990b).

Forest Service research develops ways to control the gypsy moth where forests and wildlands meet urban areas, emphasizing safe and cost-effective practices that prevent populations from increasing above harmless levels and that suppress outbreaks. The Forest Service's Forest Pest Management Staff also administers the National Center of Forest Health Management, which is active in developing and encouraging the use of integrated pest management technology for the gypsy moth. Emphasis is placed on developing biological insecticides.

ARS develops the means to protect high-value trees for yards, communities, parks, and other nonforest environments; and technology to support the activities of the Forest Service and APHIS. The APHIS Methods Development Center emphasizes development of the sterile male gypsy moth technique, and improvement of gypsy moth rearing and monitoring techniques. The CSREES plans research in cooperation with State Agricultural Experiment Stations, forestry schools, and other cooperators; and administers a research grants program and a regional research program on the gypsy moth (USDA Agricultural Research Service 1993).

Information and Education

The CSREES leads the public information and education program on gypsy moth and gypsy moth management practices (USDA 1990a). It is accomplished through cooperation with the State extension services, departments of agriculture, departments of natural resources, and other agencies.

In addition, all USDA agencies that participate in the Department's gypsy moth program conduct information and education activities to support their specific management responsibilities in the program. Education activities include developing, printing, and distributing technical publications, research reports, and briefs on the gypsy moth and gypsy moth controls; preparing and distributing slide programs and videos for use in public information and education activities; developing computer software programs and geographic information systems to assist in gypsy moth management; making presentations and participating in gypsy moth workshops; and participating in public meetings and hearings.

Timing of Activities

Activities in the gypsy moth program are complementary. Some, like prevention activities, methods development, technology transfer, research, and public information and education, are ongoing. Others depend on the development of gypsy moth life stages, on certain levels of gypsy moth populations, and on the movement of populations (*fig. B-2*).

Detection, delimiting, and other surveys are conducted throughout the year depending on the technique used and the life stage of the insect that is targeted. Most suppression, eradication, and slow-the-spread projects are conducted in spring and summer, depending on the life stage that is targeted.

Some treatments are monitored during application, or afterward to determine their effects on the environment. Evaluation of gypsy moth infestations after treatments determines their effectiveness.

Public involvement and notification activities are conducted before treatments.

Timing of activities in the gypsy moth program

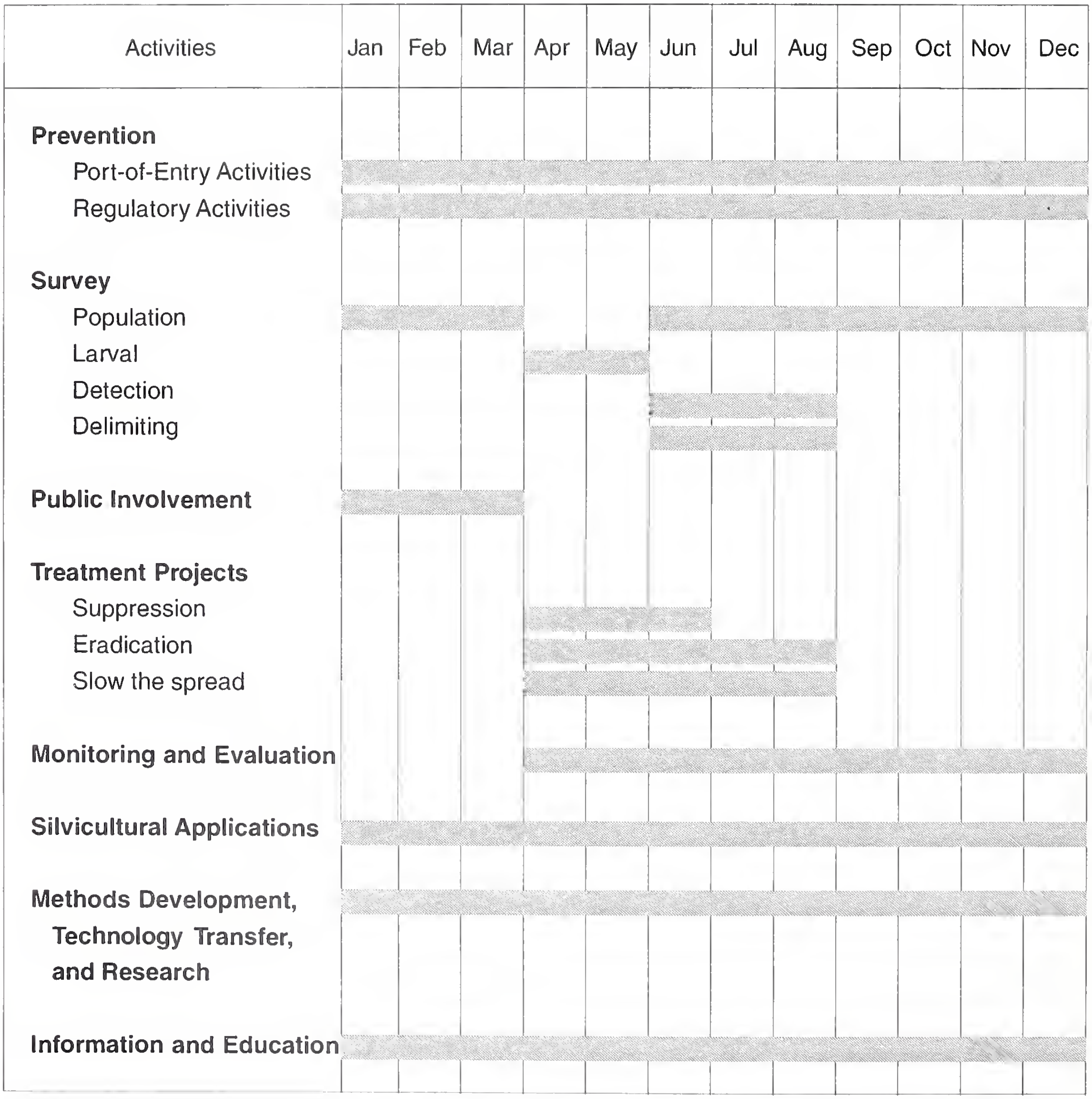
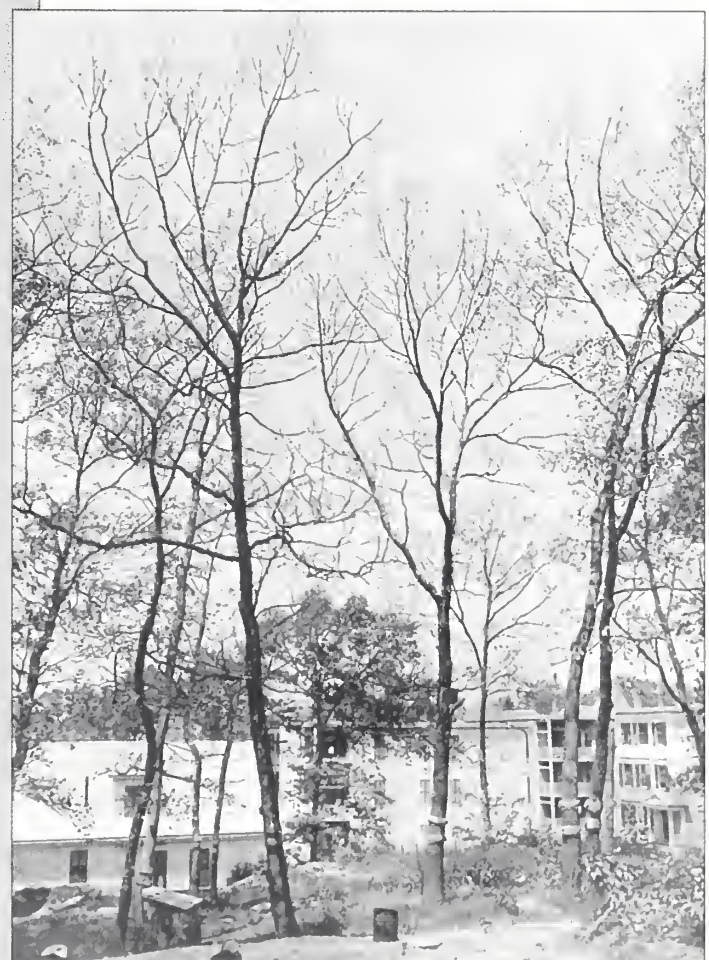


Figure B-2. The timing shown is broad and may change as the generally infested area expands into different climates.

Appendix C

Public Involvement and Issues



Oak trees stripped by gypsy moth caterpillars, Dorchester, Massachusetts, July 1895

Appendix C
Public Involvement and Issues

Contents

Public involvement was conducted to obtain the public's concerns and ideas about gypsy moth management. To identify and reach the interested and affected public across the United States, the interdisciplinary team joined with public affairs and forest pest management contacts throughout the Forest Service and Animal and Plant Health Inspection Service (APHIS). Their names are listed in *chapter 6*, Consultants and Contributors. This formal contact network also provided technical review and guidance to ensure that this environmental impact statement serves all areas of the United States.

Although public involvement activities were conducted throughout the length of the environmental impact statement project, they are described here in two time frames—before and after public comments were received in response to the November 1992 notice of intent.

Scoping Activities

The activities described in this section were conducted during the year before public comments were received in response to the November 1992 notice of intent to prepare an environmental impact statement. The purpose of the activities was to discover the public's comments, concerns, and recommendations relating to the environmental impact statement project.

A plan for public affairs and public involvement was presented and approved by the public affairs managers in July 1992. An updated plan was prepared and approved by this group in December 1993. A national mailing list was compiled, and informational materials on the environmental impact statement project and the gypsy moth problem were prepared.

On November 12, 1992, a notice was published in the *Federal Register* describing the agencies' intent to prepare an environmental impact statement and opening a formal 120-day comment period, which lasted until March 15, 1993. Comments received both before and after those dates were also reviewed by the team. News items were released to national and regional news media, and information was distributed within the Forest Service and APHIS. The Pacific Northwest Region of the Forest Service prepared information for cooperators in Washington and Oregon where a project to eradicate the Asian strain of the gypsy moth had been conducted.

In November 1992, and January and February 1993, letters asking for comments were mailed to nearly 23,000 individuals and organizations, including Federal, State and local officials; scientists; members of conservation and environmental groups; people in forestry, nursery, and related industries; homeowners and landowners in gypsy moth infested areas; American Indians; people who are physically sensitive to insecticides; and people interested in forest recreation. Letters were also distributed within the Forest Service and APHIS.

From January 1992 to January 1994 the team attended approximately 60 meetings and conducted presentations nationwide. These meetings were held before, during, and after the formal comment period of November 15, 1992, to March 15, 1993, because the team felt it was important to stay in touch with the interested public and agency managers. An exhibit, charts, and slide shows were used, including one slide show that was transferred to video. Articles appeared in *The Gypsy Moth News, The Forest Management Update, American Nurseryman, County News, Inside APHIS*, and the internal Forest Service publications *Intercom* and *Northern Region News*. All materials encouraged comments and named a contact for more information.

Outcome of Scoping

During the formal comment period 827 letters were received, all of which were acknowledged by postcard. Many more letters were received both before and after this time. Questions and information requests were answered individually.

A team from throughout the Forest Service and APHIS analyzed the letters. (Members of this Content Analysis Team are named in *chapter 6*.) The substantive comments were sorted by subject matter, and over 200 specific concerns and ideas emerged. They were organized into 10 categories:

- Effects on People
- Effects on the Environment
- Spread of the Gypsy Moth
- No Federal Program
- Program Implementation
- Parts of a Gypsy Moth Program
- Gypsy Moth Treatments and Insecticides
- Research
- Communications
- Comments Not Relevant to the Gypsy Moth

The concerns and ideas are summarized below.

Effects on People

The presence of the gypsy moth, severe defoliation, tree mortality, and treatments to control the gypsy moth, may affect people in many ways. They may affect their health, comfort, safety, and well being. They may affect their lifestyle, social setting, or activities. They may affect them economically. These concerns are listed below.

Health Concerns

Effects of the gypsy moth and treatments may be physical or emotional.

Emotional Effects

Emotional effects include aggravation of entomophobia (fear of insects) caused by the unavoidable presence of many caterpillars or pupae outdoors and surrounding the home. Emotional effects also include increased anxiety and fear about the appearance of helicopters and planes used to spray insecticides. Some people have fear or anxiety about the safety of insecticides and distrust government claims about insecticide safety, or government actions to control insects. Some comments expressed concern about unknown effects of the gypsy moth virus on human health.

Physical Effects

The majority of the human health concerns are for physical health, including the effects of insecticides on people with compromised immune systems, including those with HIV and AIDS. There is concern about the effects of spraying on people with respiratory problems, and about infections in people with lupus after spraying.

Some people are concerned about the use of insecticides that act on the insect's nervous system (organophosphates), questioning the effects they may have on human nervous and immune systems. People with a rare blood disorder (methemoglobinemia) raise concerns about exposure to diflubenzuron because it may increase the level of methemoglobin in the blood. (People with methemoglobinemia have a deficiency of the enzyme that turns methemoglobin into normal hemoglobin.) Concerns that insecticides may lead to cancer or birth defects are raised, as are concerns about the accumulated effect of insecticides in the human body after repeated exposure.

A few people are hypersensitive to chemicals and they believe that gypsy moth insecticides will or have made them ill. There are also concerns about whether the gypsy moth pheromone may be toxic to people.

The presence of gypsy moths is a common health concern, as contact with caterpillar hairs causes allergic reactions, particularly skin rashes, in some people.

Safety Concerns

Several safety concerns were raised. When gypsy moth populations are high, roads and paths could become slippery from hundreds or thousands of caterpillars and their frass. If trees weaken or die there is a hazard of trees or limbs falling and injuring people or damaging property.

Some people are concerned about possible risks of spray projects, namely insecticide spills, airplane accidents, automobile accidents, and the exposure of spray project workers to insecticides, traffic, power lines, aggressive dogs, and other neighborhood or woodland conditions.

Economic and Social Concerns

Economic and social concerns are diverse. Some relate to the presence of gypsy moths or the damage they cause; others relate to control efforts.

Concerns, which are mostly economic, include these: the negative effects on trade and commerce caused by regulations and quarantines to stop the spread of the gypsy moth into uninfested areas; the reduction or cessation of raw log imports; financial and resource losses to the pulp, paper, timber, and wood products industries if trees die; financial and resource losses to American Indian forestry enterprises; losses to organic farmers if exposure of their crops to nonnatural insecticides leads to a loss of their organic farming certification; losses in the recreation and tourism industry due to the nuisance, defoliation, health concerns, and reduced esthetics associated with gypsy moth outbreaks; and cost to property owners of maintaining weakened trees or removing dead trees, and the attendant loss in property esthetics and value.

Some concerns were mostly about control activities: whether gypsy moth control is cost-effective, whether suppression is more or less cost-effective than eradication, and the belief or perception that Federal funds used for gypsy moth control are subsidies to the timber industry. There is a concern that the nuisance of a gypsy moth outbreak does not justify Federal expenditures on insecticides and control measures. There is also a concern that both a gypsy moth infestation and control activities disrupt people's normal routine.

Effects on the Environment

Concerns about environmental effects of the gypsy moth and of control measures were widespread. The significance of this topic reflects people's interest in the health of the environment and the integrity of trees and ecosystems. Some people feel that insecticides used to control the gypsy moth may affect the environment to an unacceptable degree. Others feel that untreated defoliation is unacceptable.

Effects of the Gypsy Moth

Defoliation presents numerous concerns. The concern in watersheds is a change in rates of water retention and yield, particularly in the arid West. Defoliation and frass along and in waterways could affect aquatic ecosystems through changes in water temperature, nutrient load, and habitat suitability for aquatic insects and fish. Another concern is reduced quality of drinking water.

There were some comments that stands may become more resilient to damaging effects of the gypsy moth through repeated outbreaks. Other concerns are that defoliation and tree death, including loss of oaks, would change the composition of eastern hardwood forests, lead to the invasion of nonnative plants, and negatively affect old growth forests, numbers of species, and mast production. There is concern too that soil characteristics would change, and that there would be long-term effects on forest composition, productivity, and numbers of species including prey-predator relationships. Dead trees would lead to increased fire hazard.

Some comments noted that the gypsy moth is not a problem, and that suppression activities will have more serious environmental effects than the insect will.

Effects of Treatments

Environmental concerns about insecticides include these: the persistence of insecticides in the environment; the fate and effect of insecticides when they break down through time and exposure; and their bioaccumulation in the food chain. Other concerns are the cumulative and synergistic effects of repeated treatments on wildlife, Lepidoptera, and their food chains—whether treatments are applied more than once per season, in multiple or consecutive seasons.

Through disturbance of the environment, habitat, cover, or food supplies there is concern that gypsy moth insecticides could kill, sicken, weaken, or harm other Lepidoptera, especially endangered ones. The same concerns extend to other endangered species,

birds, bats, rodents, gypsy moth parasites and predators, native and beneficial insects, millipedes, Collembolla, and mites.

A concern was raised about the indirect effect of *B.t.* on mice and other animals that are sensitive to alpha-exotoxin. Some people think that this toxin could be produced in the cadavers of caterpillars that have consumed *B.t.* The concern is that cadavers may be eaten by these other animals, which may die from the alpha-exotoxin.

There is concern that insecticides contaminate drinking water and that insecticide ingredients and formulations, including spreaders, stickers, and inert ingredients affect aquatic ecosystems.

Noninsecticidal treatments raise other concerns, specifically the long-term effects of parasites, predators, diseased trees, and silviculture used to minimize damage. A specific concern about silviculture is the effects of removing resistant genotypes of susceptible tree species.

Spread of the Gypsy Moth

The continued spread of the European strain of the gypsy moth and the establishment of the Asian strain are concerns. Some people feel that efforts to slow the spread of the gypsy moth or stop the introduction of the Asian strain of the gypsy moth are not worthwhile. They feel that these insects will eventually infest all susceptible U.S. forests "no matter what we do." Others feel exactly the opposite: habitat changes, losses, and costs associated with defoliation, tree mortality, and suppression are too great not to take action.

Spread of the European Strain

People are concerned that the European strain of the gypsy moth and its damaging effects are spreading throughout the United States where there are suitable hosts. There is interest in preventing gypsy moth populations from increasing and also from spreading artificially—when people transport infested items, such as logs, vehicles, and nursery stock, to uninfested areas.

The spread of the gypsy moth raised concerns about the need to protect high-value timber stands and popular recreation areas. Some comments expressed the need to protect forest health and ecosystems—others believe the gypsy moth is now part of U.S. ecosystems and feel its spread should be speeded up to get its inevitable establishment "over and done with." Some comments show that people have reservations about efforts to slow the spread of the European strain of the gypsy moth. Is it feasible? Is it reasonable? Is it affordable?

Spread of the Asian Strain

There are concerns about the establishment of the Asian strain of the gypsy moth in the United States, and the effects of it reproducing with the European strain. There is recognition and concern that the Asian strain can enter through any port. Some comments state that the Asian strain is a greater threat to ecosystems, forests, and trees because it will feed on a greater number of host trees and plants than the European strain.

Comments note that the consequences of not eradicating the Asian strain would be higher costs to suppress its damage and a greater magnitude of control activities because of expected rapid spread.

No Federal Program

What might happen without a national gypsy moth management program? This is a fundamental question because it gives a baseline of comparison for the questions related to gypsy moth management. It helps people decide which program elements and actions are worthwhile based on personal values, environmental considerations, economics, and other factors.

In the absence of Federal participation and leadership in a national gypsy moth management program, there would be concerns about human health, the environment, and ecosystems.

Without a Federal program, there is the likelihood that people not trained in insecticide use would undertake gypsy moth control, increasing human health and environmental risks by using a

broader range of insecticides, harsher insecticides, and greater application rates than necessary. Concerns also note that without Federal cost-sharing some State gypsy moth programs would be in jeopardy. There would be more defoliation and damage to forests, wildlife, and other valued resources.

Several comments on "no Federal program" note positive outcomes. The gypsy moth might make stands more resilient and resistant to subsequent outbreaks. It would create healthier forests by culling weak trees and providing food for birds and homes for cavity nesting birds. There would be Federal cost savings. The inevitable infestation of all susceptible areas of the United States would not be prolonged.

Program Implementation

Program implementation is critical if a gypsy moth management program is to be effective and efficient: if time, effort, and money are to be expended wisely and achieve results. Comments on the design and implementation of a Federal gypsy moth management program, plus coordination with other Federal, State, and international programs, were as follows.

Canada and the United States should coordinate their programs. The Federal program disseminates information on various control projects among States, which aids information flow, coordination, and technology transfer. Entomologists should only provide technical advice and not make policy.

Comments on program staffing said that, in some States, volunteers make projects possible with the help of matching USDA funds. The program could help provide jobs for the unemployed and could be a way for students to work off student loan obligations.

The topic of treatment locations and priorities generated many comments. Should urban residential areas or rural forest areas or both be treated? Should public, private, or commercial forests be treated? There is concern whether the transition area, the generally infested area, isolated populations, or low level populations should be treated. Similarly, there is concern whether newly infested but previously untreated areas should receive treatment, and whether long-infested, previously treated areas should continue to be treated. Some people believe that only special areas, such as endangered species habitat, recreational sites, natural landmarks, and high value forest stands, should be treated.

People are concerned about the effectiveness of treatments when public land adjacent to private land does not get sprayed, and vice versa. This is similar to the concern about potential spray blocks being skipped when participation in spray projects is voluntary. There is a question whether using relatively small spray blocks leads to effective control. In some locations landowners must sign up for spraying by September 1, which is too early, since egg mass counts (which help predict next year's defoliation) are not available until October or November.

Other concerns about program implementation are perceived inequities in landowners' eligibility to benefit from cooperative funding at the State and local level; spraying between 6:30 a.m. and 9 a.m. when children are going to school; and that forest management for the gypsy moth is an excuse or justification for timber cutting on public lands.

Parts of a Gypsy Moth Program

This category focuses on the elements of a gypsy moth program and how they would complement each other.

Integrated Pest Management

Concerns about integrated pest management are that it should be more than just spraying, and similarly, that the current program is perceived as "spray only." The integrated pest management program should shift in emphasis from control to prevention of damage and should emphasize minimizing outbreaks. Education and monitoring should be viewed with importance equal to control measures.

Monitoring

Concerns noted that the effects and effectiveness of treatments should be monitored; that monitoring should be conducted more effectively and should be done before, during, and after treatment; that early detection is a priority; that funds for monitoring are needed; that local governments should be allowed to participate in monitoring; and that Federal lands in Colorado are inadequately monitored.

Suppression

Concerns about suppression are that it is a short-term bandage measure. Some people wrote that it is of questionable value and fairness because public monies are used to treat private lands, plus some infested lands receive no treatment. Similar concerns are that suppression is uneconomical in the long run and amounts to subsidized private spraying. There are questions and concerns about the cumulative effects of suppression.

There was a note that the National Forest System appeals process can delay treatment long enough to make it infeasible, based on the life stage of the insect.

Eradication

Comments supporting eradication stated that eradication of the Asian strain of the gypsy moth will save money and prevent situations associated with its rapid spread. Some people favor aggressive eradication of this pest. Some people feel new methods of eradication are needed.

Comments critical of eradication stated that it is an unrealistic goal, an unnecessary expense, and prolongs the inevitable. Concerns are about damage to other species and ecosystems.

Exclusion

Concerns about exclusion note that gypsy moth traps should be set out in Pacific Northwest port areas. Some people say that traps should be set out in all ports, and all shipments should be inspected. There are suggestions to treat ships in Russian ports, to consider embargoes, to strengthen measures to prevent importation of foreign pests, and to inspect all foreign wood and wood products.

Slow the Spread

Comments on slow the spread are that it will provide more time for research, methods development, and preventive measures that may improve gypsy moth management in the future, although the infestation will continue to spread as the slow-the-spread strategy is tried. There is a concern that the States' role in slow the spread must be clarified.

Quarantine

The subject of quarantine generated many specific concerns and ideas. There were comments that uninfested States are more in favor of quarantines than are infested States; inspections and quarantines should be strengthened, be more aggressive, and be more effective; Federal and State governments should cooperate more closely; and inexperienced people should not be allowed to inspect and certify that goods are free of the gypsy moth.

There are concerns about spread of the gypsy moth on firewood and nursery stock. The transport of firewood should be limited to avoid spreading the gypsy moth to uninfested areas. There is concern that tree trimmers and loggers need more education in this area and their work relating to gypsy moth quarantines needs to be monitored. Ways to disinfect items such as wood products and nursery stock are needed, as is more public awareness of the quarantine. The use of mass media for public awareness was recommended.

The concept of high- and low-risk regulated areas should be eliminated. The regulated shipping points manual, which helps to determine the status of a shipment, should be revised. There is a concern to restrict the time allowed on certificates for moving regulated items to eliminate the possibility of moving several loads under the same certificate. The economic effects of quarantines must be evaluated.

Preventive Measures and Mechanical Controls

There is a concern about the cost effectiveness of scraping egg masses from trees and applying burlap bands or Tanglefoot to control the gypsy moth. People recommended planting gypsy-moth-resistant tree species, using silviculture to prevent or minimize damage, and improving habitat for gypsy moth predators ahead of the transition area.

Gypsy Moth Treatments and Insecticides

Gypsy moth treatments that are approved for use in a national program must be safe, effective, available, and cost efficient.

Chemical Insecticides

Comments supportive of chemical insecticides stated that they are faster acting, less expensive, and more trouble-free to use than microbial insecticides. Chemical insecticides usually work in one application, compared with microbials needing two or more applications. The environmental impact statement should maintain the option of using the chemical insecticides acephate, carbaryl, and trichlorfon.

Other comments about chemical treatments stated that the public is often less willing to support use of these or nonspecific insecticides than they are the microbial insecticides. There are concerns that chemicals have greater environmental effects and less public acceptance or approval.

Nonchemical Insecticides and Treatments

Comments and concerns about nonchemical insecticides and treatments stated that inherited sterility, sterile male moths, other genetic-based controls, and biological insecticides should be made operational. Limited availability of the gypsy moth virus concerns many people.

Safety and Effectiveness

There are concerns about the effectiveness of all treatment methods including how quickly an insecticide acts, its cost and application method, plus the efficacy of formulations compared with the number of treatments required. There are concerns about the unknown human health and environmental effects of inert ingredients, spreaders, stickers, other additives, and ingredients that are trade secrets.

People question the possible undesirable effects of the metabolites that result when insecticides break down, of insecticides persisting in the environment, and of drift during and after application.

Research

Comments about research generally recognize it as critical to understanding the effects of the gypsy moth and the effects of treatment, and as a path to better management in the future.

Research Suggested on Treatments and Methods

Suggestions on treatments and methods are these: do more research on developing environmentally acceptable control methods; do a cost-benefit analysis of treatments; find the ideal new pesticide that is not toxic to mammals, pets, or the environment; compare the benefits of treatment versus no treatment; explore the role of fire in gypsy moth control; and determine the appropriate block size for each treatment.

Research Suggested on Treatment Effects

Research suggestions on treatment effects are as follows. Study the long-term effects of both the gypsy moth and treatments, including effects on

nontarget organisms, and threatened and endangered species. Do definitive research on long-range effects of insecticides on the environment and especially water supply. Conduct environmental fate studies that are specific to the proposed site—Alaskan studies may be needed. Study whether plantation farming and extensive pesticide use are underlying causes of gypsy moth infestation.

Do environmental risk assessments of control substances and gypsy moth effects; gain the latest and best information on potential environmental impacts of any proposed insecticide; and inform decisionmakers.

Research Suggested on Gypsy Moth Infestations

Suggestions included these: find out if vitamins C and E will increase a tree's natural defenses; research newly infested and historically infested areas; study ways to protect old-growth forests from gypsy moth infestations; study the gypsy moth's ecology; and study the effects of defoliation and of altering the insect's genetics or food supply.

Other Ideas

Other ideas related to research were these: find effective, inexpensive ways to disinfect imported logs; award research contracts on a truly open and competitive basis; and do a detailed problem analysis to see what information is needed.

Communications

Although the gypsy moth has a 125-year history in the United States and is a growing problem, most people do not seem to care until it reaches their backyard. When it does, there may be anguish, outrage, and desperation to kill the caterpillars. Harsh chemicals or ineffective measures may be used because awareness of and planning for the gypsy moth has not occurred. Many people feel that improved communications are critical, to help communities prepare for and deal with the gypsy moth, and to improve interagency coordination.

There were many long and fervent comments, briefly summarized as follows. Much more emphasis on information and education is needed than is presently given. Education should be conducted via the environmental impact statement and should continue as a program element when the environmental impact statement is done. Technology transfer should be done.

More public involvement should be done in program implementation. Residents, schools, and local officials need to be notified about spray operations.

Comments Not Relevant to the Gypsy Moth

There were a number of concerns and comments on natural resource issues, such as timber, that are not relevant to gypsy moth management and are not addressed in this environmental impact statement. People who would like more information on such issues may write to: Chief, USDA Forest Service, P.O. Box 96090, Washington, DC 20090-6090.

Comments related to acid rain state that it is a more serious threat than the gypsy moth but is not being well addressed. Miscellaneous comments included criticism about government officials not listening to the public, and the need for forest managers to serve as the gypsy moth policy managers with entomologists serving only a technical advisory role.

How the Comments Were Used

The comments confirmed the need for a new program by identifying people's specific problems with the gypsy moth or treatments, and have shaped this document in a number of ways.

Many of the comments helped in developing the range of alternatives. The alternative of suppression only (alternative 2) was suggested by public comment.

The comments helped the interdisciplinary team use an ecological approach, by identifying ecosystem, social, and economic components of the environment affected by the gypsy moth, which were analyzed and are described in *chapter 3* on the Affected Environment.

The comments provided guidance and were of exceptional value in planning and preparing *chapter 4* on Environmental Consequences. The comments helped the preparers identify components of human health and ecosystems for close scientific study in the two risk assessments conducted to support this environmental impact statement (*app. F* and *G*). The results of those studies are summarized in *parts A* and *B* of *chapter 4*.

Some comments led to measures that are recommended to mitigate the effects of treatments or effects of the gypsy moth.

Two appendixes were created to give information for which the comments showed a need. *Appendix B* describes all parts of USDA's gypsy moth program, including quarantine, exclusion, survey, monitoring, and information and education. *Appendix A* describes all treatments considered for this environmental impact statement, including various natural control agents and silviculture, and why some would not be suited to a national gypsy moth management program.

The majority of concerns that are within the scope of this document surround these fundamental issues about the gypsy moth:

1. How does the presence of the gypsy moth affect people and the environment?
2. How do the insecticide treatments applied to the gypsy moth affect people and the environment?
3. How do the noninsecticidal treatments applied to the gypsy moth affect people and the environment?

These issues are broad because the purpose of this environmental impact statement is to set national program guidelines and national direction for managing the gypsy moth. Local concerns will be addressed by further environmental analysis at the local level, which must be completed before site-specific treatments can be conducted.

Continued Public Involvement Activities

This section describes the public involvement activities conducted in the 2 years after the receipt of public comments from scoping. The purpose of the activities was to obtain the public's feedback about the alternatives and analysis in the draft environmental impact statement.

Three mass mailings to the project's national mailing list were completed in October 1993, May 1994, and December 1994. The October 1993 mailing described in general the public comments and how they would be used. The May 1994 mailing provided information on the project's status and contents of the draft document, and asked recipients whether they wished to receive a complete draft environmental impact statement or just the summary. The December 1994 mailing introduced the alternatives and noted that the draft environmental impact statement would be published early in 1995.

Personalized letters were sent to 52 individuals and organizations in March and April 1994, to provide additional information or invite feedback.

From February 1994 to March 1995, the interdisciplinary team gave presentations about the environmental impact statement at 12 conferences attended by interested individuals.

Articles about the environmental impact statement were published in *Gypsy Moth Exotica* and the *Delaware Gypsy Moth Newsletter* (both January 1994), the *Earth First!* newsletter (February 1994), the newsletter of the West Virginia Entomological Society, and the USDA Forest Service Northeastern Area's newsletter *News for the Northeast* (both March 1995), and *American Nurseryman* (August 1995). In February 1995 information about the environmental impact statement was posted on the Internet, on the Northeastern Area's home page.

Briefs for Forest Service and APHIS cooperators were mailed in March and August 1994. In February 1995 letters were sent and followup telephone calls were made to 36 cooperators to assess the need for public involvement meetings about the draft document. Each cooperator felt that public involvement meetings were not necessary in their State.

Communications to the Forest Service and APHIS contact network and other staff members included the *EIS Bullets* (a weekly or biweekly progress report) and six updates that focused on specific topics or project news. The formal contact network was provided with handout materials and other items to assist with public outreach.

The draft environmental impact statement was published in April 1995, and the notice of its availability was published in the *Federal Register* on May 12, 1995. The complete draft EIS was mailed to 2,258 people who had requested it, and to 407 depository libraries throughout the United States and Puerto Rico. The summary was mailed to 10,735 people.

Three news stories about the availability of the draft environmental impact statement were distributed to 10,000 newspapers nationally on May 5, May 19, and June 2. The stories were also posted on the Internet, on the home page of News USA, Inc. At least 134 newspapers in 37 States published information about the draft environmental impact statement. This information reached potentially between 1.2 million and 4.0 million readers, based on circulation figures and estimated shared readership among household members or others in addition to the principal subscriber.

On June 15 a public service announcement was sent to 6,000 radio stations nationally. The announcement was aired 2,742 times on at least 313 radio stations in 38 States reaching an audience of at least 21 million people.

A one-half page public announcement about the availability of the draft environmental impact statement appeared in the May-June issue of *American Forests* magazine. Information about availability also appeared in the *Chesapeake Bay Journal*, the National Association of State Foresters' *Washington Update*, and the *Gypsy Moth News*. These magazines and newsletters reached more than 80,000 interested citizens, in addition to the direct mail and mass media outreach. Information about the availability of the draft environmental impact statement was also posted on the National Association of Counties' electronic mail bulletin board.

A notice was distributed to Forest Service and APHIS employees encouraging them to comment on the draft environmental impact statement, and an article appeared in the Forest Service newsletter *Short Subjects and Timely Tips for Pesticide Users.*

In response to the draft environmental impact statement, 146 letters were received. In August 1995 an acknowledgment postcard was sent to everyone who gave comments.

A contractor analyzed the content of the letters and organized the substantive comments. The interdisciplinary team used the comments in preparing this final environmental impact statement. The comments and responses to them are summarized in *appendix H.*

News about the availability of the draft environmental impact statement appeared in at least 134 newspapers and aired on at least 313 radio stations.

Appendix D

Plant List

Feeding and ballooning of gypsy moth caterpillars

Plant List

This appendix shows the susceptibility of plant species to feeding by gypsy moth caterpillars (Liebhold and others 1995). The susceptibility is based on preference and weight gain of both European and Asian strains of the gypsy moth, and takes into account that preference varies between the strains. The index numbers provide a general ranking:

1—susceptible
2—resistant
3—immune.

These terms, suggested by Montgomery (1991), indicate the likelihood that a plant will be defoliated. Plant names were taken from several sources (Dirr 1990, Little 1979, Rehder 1951, Taylor 1961, Van Dersal 1938, Viertel 1970).

Genus and species	Common name	Susceptibility index
Abelia grandiflora	glossy abelia	3
Abies amabilis	Pacific silver fir; silver fir; lovely fir; amabilis fir	2
Abies balsamea	balsam fir; Canada balsam; eastern fir	3
Abies balsamea var. *phanerolepis*	balsam fir; bracted balsam fir	3
Abies bifolia	Rocky Mountain subalpine fir	3
Abies bracteata	bristlecone fir; Santa Lucia fir; silver fir	2
Abies concolor	white fir; concolor fir; silver fir	2
Abies fraseri	Fraser fir; southern balsam fir; southern fir	3
Abies grandis	grand fir; lowland white fir; lowland fir; balsam fir	2
Abies holophylla	needle fir; Manchurian fir	2
Abies lasiocarpa	subalpine fir; alpine fir; balsam fir; white balsam fir; Rocky Mountain fir	2
Abies lasiocarpa var. *arizonica*	corkbark fir	2
Abies lowiana	California white fir; white fir; Sierra white fir	2
Abies magnifica	California red fir; red fir; silvertip; golden fir	2
Abies procera	noble fir; red fir; white fir	2
Acacia baileyana	Bailey acacia; cootamundra wattel	2
Acacia farnesiana	huisache; sweet acacia; Texas huisache; cassie	2
Acacia greggii	Gregg catclaw; catclaw acacia; Texas catclaw; devilsclaw; long-flowered catclaw	2
Acacia koa	koa acacia	2
Acacia longifolia	golden wattle; Sydney golden wattle	2
Acacia spp.	acacia	2
Acacia tortuosa	huisachillo; catclaw; twisted acacia; Rio Grande acacia	2
Acacia wrightii	Wright catclaw; Texas catclaw; Wright acacia	2
Acer barbatum	Florida maple; sugar maple; hammock maple	2
Acer campestre	hedge maple; English field maple	2
Acer circinatum	vine maple	2
Acer dasycarpum	silver maple; cut-leaf maple	2
Acer ginnala	amur maple	3
Acer glabrum	Rocky Mountain maple; dwarf maple; mountain maple; Sierra maple	2
Acer grandidentatum	canyon maple; bigtooth maple; sugar maple; Uvalde bigtooth maple	2

Genus and species	Common name	Susceptibility index
Acer japonicum	fullmoon maple	2
Acer leucoderme	chalk maple; white-bark maple	2
Acer macrophyllum	bigleaf maple; Oregon maple; broadleaf maple	2
Acer negundo	boxelder; ash-leaved maple; boxelder maple; Manitoba maple	2
Acer nigrum	black maple; black sugar maple; hard maple; rock maple	2
Acer palmatum	Japanese maple	2
Acer pensylvanicum	striped maple; moosewood	3
Acer platanoides	Norway maple	2
Acer pseudoplatanus	planetree maple; sycamore maple	2
Acer rubrum	red maple; scarlet maple; swamp maple; soft maple	2
Acer saccharinum	silver maple; soft maple; river maple; silverleaf maple	3
Acer saccharum	sugar maple; hard maple; rock maple	2
Acer spicatum	mountain maple; moose maple	3
Acer tartaricum	tartarian maple; Tartar maple	2
Achras emarginata	wild-dilly	2
Aesculus californica	California buckeye	3
Aesculus glabra	Ohio buckeye; fetid buckeye; stinking buckeye; American horsechestnut	2
Aesculus hippocastanum	horsechestnut; common horsechestnut	3
Aesculus octandra	yellow buckeye; sweet buckeye; big buckeye	3
Aesculus pavia	red buckeye; scarlet buckeye; woolly buckeye; fire-cracker-plant	2
Aesculus sylvatica	painted buckeye; dwarf buckeye; Georgia buckeye	2
Ailanthus altissima	ailanthus; tree of heaven; Chinese tree-of-heaven; copaltree	2
Albizia julibrissin	silktree; mimosa; mimosa-tree; powderpuff-tree	3
Aleurites fordii	tung-oil-tree; tungtree	2
Alnus maritima	seaside alder	1
Alnus oblongifolia	Arizona alder; Mexican alder; New Mexican alder	1
Alnus rhombifolia	white alder; Sierra alder	2
Alnus rubra	red alder, Oregon alder, western alder, Pacific Coast alder	1
Alnus rugosa	speckled alder; smooth alder; tag alder; gray alder; hoary alder; hazel alder	1
Alnus serrulata	hazel alder; smooth alder; common alder; tag alder; black alder	2
Alnus sinuata	Sitka alder; mountain alder; wavyleaf alder	2
Alnus tenuifolia	mountain alder; thinleaf alder; river alder	1
Alvaradoa amorphoides	Mexican alvaradoa	2
Amelanchier alnifolia	western serviceberry; saskatoon serviceberry; serviceberry; juneberry; western shadbush	2
Amelanchier arborea	downy serviceberry; Allegheny serviceberry; shadblow; apple shadbush	2
Amelanchier canadensis	thicket serviceberry; oblongleaf juneberry	2
Amelanchier laevis	Allegheny serviceberry; downy serviceberry; smooth serviceberry	2
Amelanchier spp.	serviceberry	2
Amyris elemifera	torchwood; candlewood; sea amyris	2
Annona glabra	pond-apple; alligator-apple	2
Aralia spinosa	devils-walkingstick; Hercules-club; prickly-ash; angelica-tree	3
Arbutus arizonica	Arizona madrone; madrona; Arizona madrono	2
Arbutus menziesii	Pacific madrone; madrone; madrona	1
Arbutus texana	Texas madrone; madrona	2
Arbutus unedo	strawberry madrone; strawberrytree	2
Ardisia escallonioides	marlberry; marbleberry	2
Ardisia japonica	Japanese ardisia; marlberry	3
Arecastrum romanzoffianum	queen palm; plumy coconut	3
Asimina triloba	pawpaw; common pawpaw; pawpaw apple; false-banana	2
Avicennia nitida	black-mangrove; blackwood	2

Plant List

Genus and species	Common name	Susceptibility index
Betula alba	European white birch; white-barked canoe birch; cut-leaved birch	2
Betula alleghaniensis	yellow birch; gray birch; silver birch; swamp birch	3
Betula caerulea	blueleaf birch	1
Betula eastwoodiae	Yukon birch	1
Betula lenta	sweet birch; black birch; cherry birch	2
Betula nigra	river birch; red birch; black birch; water birch	1
Betula occidentalis	water birch; red birch; black birch; spring birch; paper birch	2
Betula papyrifera	paper birch; canoe birch; white birch; silver birch	1
Betula pendula	European birch; European white birch; cut-leaf weeping birch; blueleaf birch	1
Betula populifolia	gray birch; grey birch; white birch; wire birch; fire birch; oldfield birch	1
Betula pumila	swamp birch; bog birch	1
Betula verrucosa	European white birch	1
Bourreria ovata	Bahama strongback; Bahama strongbark; strongback	3
Broussonetia papyrifera	paper mulberry; common paper mulberry	3
Bumelia lanuginosa	gum bumelia; woolly buckthorn; chittamwood; swiftwig-gum; gum elastic; buckthorn	2
Bursera simaruba	gumbo-limbo; West-Indian-birch; gum-elemi	2
Callitris glaucophylla	white cypress-pine	3
Calocedrus decurrens	incense-cedar	3
Calycanthus floridus	common sweetshrub; Carolina allspice; hairy (Caroline) allspice	3
Calyptranthes pallens	pale lidflower; spicewood; white spicewood	2
Calyptranthes zuzygium	myrtle-of-the-river; spicewood	2
Canella winterana	canella; cinnamonbark; wild-cinnamon	2
Canotia holacantha	canotia; Mohave thorn; crucifixion-thorn	2
Capparis cynophallophora	Jamaica caper; capertree; Jamaica capertree	2
Caragana arborescens	peatree; peashrub; Siberian peashrub; Siberian pea tree	2
Carica papaya	papaya; pawpaw	2
Carpinus caroliniana	American hornbeam; blue-beech; water-beech	2
Carya aquatica	water hickory; bitter pecan; swamp hickory; bitter water hickory	2
Carya cordiformis	bitternut hickory; bitternut; swamp hickory; pignut; pignut hickory	2
Carya floridana	scrub hickory; Florida hickory	2
Carya glabra	pignut hickory; pignut	2
Carya illinoensis	pecan; sweet pecan	2
Carya laciniosa	shellbark hickory; big shellbark hickory; king nut hickory; big shagbark hickory	2
Carya leiodermis	pignut hickory; swamp hickory	2
Carya myristiciformis	nutmeg hickory; swamp hickory; bitter water hickory	2
Carya ovalis	red hickory; small pignut; sweet pignut	2
Carya ovata	shagbark hickory; shellbark hickory; upland hickory; scalybark hickory	3
Carya pallida	sand hickory; pignut hickory; pale hickory; pallid hickory	2
Carya spp.	hickory	2
Carya texana	black hickory; bitter pecan; Buckley hickory; pignut hickory	2
Carya tomentosa	mockernut hickory; mockernut; white hickory; whiteheart hickory	2
Caryota urens	toddy palm; white palm; fishtail palm; wine palm	3
Castanea dentata	American chestnut; chestnut	2
Castanea ozarkensis	Ozark chinkapin; Ozark chestnut	2
Castanea pumila	Allegheny chinkapin	2
Castanopsis chrysophylla	giant chinkapin; golden chinkapin; giant evergreen chinkapin	1
Casuarina equisetifolia	horsetail casuarina; beefwood; Australian pine; horsetail-tree	2
Casuarina stricta	coast beefwood	2
Catalpa bignonioides	southern catalpa; common catalpa; catawba; Indian-bean; cigartree	3
Catalpa speciosa	northern catalpa; hardy catalpa; western catalpa; catawba	3

Genus and species	Common name	Susceptibility index
Catalpa spp.	catalpa; hardy catalpa	3
Ceanothus arboreus	feltleaf ceanothus; island myrtle; Catalina ceanothus	3
Ceanothus integerrimus	deer brush	3
Ceanothus maritimus		2
Ceanothus spinosus	greenbark ceanothus; spiny ceanothus; redheart ceanothus; California-lilac	3
Ceanothus spp.	ceanothus	3
Ceanothus thysiflorus	blueblossom; blue-myrtle; blue-brush; blueblossom ceanothus	3
Cedrus atlantica	atlas cedar	2
Cedrus deodara	deodar cedar	2
Cedrus libani	Cedar of Lebanon	2
Celtis laevigata	sugarberry; southern hackberry; Mississippi hackberry; Texas sugarberry	3
Celtis occidentalis	hackberry; northern hackberry; sugarberry; nettletree	3
Celtis tenuifolia	Georgia hackberry; dwarf hackberry; upland hackberry	3
Cephalanthus occidentalis	buttonbush; buttonball bush; honey-balls; globeflowers	2
Cercidium floridum	blue paloverde; Texas paloverde; paloverde	2
Cercidium microphyllum	yellow paloverde; littleleaf hornbean; foothill paloverde; littleleaf paloverde	2
Cercis canadensis	eastern redbud; redbud; Judas tree	3
Cercis occidentalis	California redbud; western redbud; Arizona redbud	3
Cercocarpus betuloides	birchleaf cercocarpus; birchleaf mountain-mahogany; alderleaf cercocarpus	2
Cercocarpus breviflorus	hairy cercocarpus; Wright mountain-mahogany; hairy mountain-mahogany	2
Cercocarpus intricatus	little leaf mountain-mahogany	2
Cercocarpus ledifolius	curlleaf cercocarpus; mountain-mahogany; curlleaf mountain-mahogany	2
Cercocarpus montanus	alderleaf cercocarpus; alderleaf mountain-mahogany; mountain-mahogany; true mountain-mahogany	2
Cereus giganteus	saguaro; giant cactus; pitahaya	2
Chamaecyparis lawsoniana	Port-Orford-cedar; Port-Orford white-cedar; Oregon-cedar; Lawson cypress	3
Chamaecyparis nootkatensis	Alaska-cedar; Nootka cypress; Alaska yellow-cedar; Sitka cypress	3
Chamaecyparis thyoides	Altantic white-cedar; Atlantic cedar; white-cedar; southern white-cedar	3
Chilopsis linearis	desert-willow; desert-catalpa	3
Chionanthus virginicus	fringetree; fringe tree; old-mans-beard	2
Chrysobalanus icaco	cocoplum; icaco coco-plum; smallfruit cocoplum; Everglades cocoplum	2
Chrysophyllum oliviforme	satinleaf	2
Cinnamonum camphora	camphor-tree	1
Citharexylum fruticosum	fiddlewood; Florida fiddlewood	2
Citrus aurantifolia	lime; key lime	2
Citrus limon	lemon	3
Citrus sinensis	orange; navel orange; sweet orange	2
Cladrastis lutea	yellow-wood	2
Clethra alnifolia	sweet pepperbrush; summersweet clethra	3
Clethra spp.	clethra; pepperbush	3
Cliftonia monophylla	buckwheat-tree; titi; black titi	2
Coccoloba diversifolia	pigeon-plum; doveplum; tie-tongue	2
Coccoloba uvifera	seagrape; grape-tree	2
Coccothrinax argentata	Florida silverpalm; Biscayne-palm; brittle thatch; thatchpalm	3
Cocos nucifera	coconut; coconut palm	3
Colubrina reclinata	soldierwood	2
Conocarpus erectus	button-mangrove; buttonwood; silver buttonwood	2
Cordia sebestena	geiger-tree	3
Cornus alternifolia	alternate-leaf dogwood; blue cornel	3
Cornus drummondii	roughleaf dogwood	3

Plant List

Genus and species	Common name	Susceptibility index
Cornus florida	flowering dogwood; dogwood; cornel; boxwood	2
Cornus nuttallii	Pacific dogwood; flowering dogwood; mountain dogwood	3
Cornus racemosa	gray dogwood	3
Cornus rugosa	roundleaf dogwood; roundleafed cornel	3
Cornus spp.	dogwood; cornel	3
Cornus stolonifera	red-osier dogwood; American dogwood; redstem dogwood; kinnikinnik	3
Corylus americana	American hazelnut; American filbert; wild hazelnut	1
Corylus avellana	European hazelnut; European filbert	1
Corylus avena		1
Corylus cornuta	beaked hazelnut; beaked filbert; western hazelnut	2
Corylus rostrata	beaked hazelnut	1
Cotinus coggygria	smoketree; common smoketree	1
Cotinus obovatus	American smoketree; smoketree; chittamwood; yellowwood	1
Cotoneaster pyracantha	firethorn; everlasting thorn	1
Cowania mexicana	cliffrose; Stansbury cliffrose; quininebush	2
Crataegus berberifolia	barberry hawthorn; bigtree hawthorn; barberryleaf hawthorn	1
Crataegus boyntonii	Biltmore hawthorn; Boynton hawthorn	1
Crataegus brachycantha	blueberry hawthorn; blue haw; pommette blue	1
Crataegus coccinea	scarlet hawthorn; scarlet haw	1
Crataegus crus-galli	cockspur hawthorn; hog-apple; cockspur-thorn; Newcastle thorn	1
Crataegus douglasii	black hawthorn; Douglas hawthorn; river hawthorn	1
Crataegus induta	downy hawthorn; turkey hawthorn	1
Crataegus marshallii	parsley hawthorn; parsley-leaf hawthorn	1
Crataegus mollis	downy hawthorn	1
Crataegus monogyna	oneseed hawthorn; singleseed hawthorn; English hawthorn; European hawthorn	2
Crataegus opaca	riverflat hawthorn; English hawthorn; May hawthorn; May haw; apple haw	1
Crataegus oxyacantha	English hawthorn	1
Crataegus pedicellata	scarlet hawthorn	1
Crataegus pruinosa	frosted hawthorn; waxy-fruit thorn	1
Crataegus pyracantha	firethorn; white thorn	1
Crataegus saligna	willow hawthorn	1
Crataegus spathulata	littlehip hawthorn; small-fruit hawthorn; pasture hawthorn	1
Crataegus spp.	hawthorn	1
Cunninghamia lanceolata	China fir; blue Chinese fir	3
Cupressocyparis leylandii	Leyland cypress	3
Cupressus arizonica	Arizona cypress	3
Cupressus bakeri	Baker cypress; Siskiyou cypress; Modoc or MacNab cypress	3
Cupressus goveniana	Gowen cypress	3
Cupressus guadalupensis	Guadalupe cypress; Forbes' cypress; Tecate cyress	3
Cupressus macnabiana	MacNab cypress	3
Cupressus macrocarpa	Monterey cypress	3
Cupressus sargentii	Sargent cypress	3
Cydonia japonica	common flowering quince; dwarf Japanese quince; Japan quince	2
Cydonia vulgaris	quince	2
Cyrilla racemiflora	swamp cyrilla; swamp ironwood; leatherwood	2
Dalea spinosa	smokethorn; smoketree; indigobush	2
Diospyros texana	Texas persimmon; black persimmon; Mexican persimmon	3
Diospyros virginiana	persimmon; common persimmon; eastern persimmon; possumwood	3
Dipholis salicifolia	willow bustic; bustic; willow-leaf bustic; cassada	2
Drypetes lateriflora	Guiana-plum	3

Genus and species	Common name	Susceptibility index
Elaeagnus angustifolia	Russian-olive; oleaster	3
Elaeagnus hortensis	oleaster	2
Elliottia racemosa	elliottia; southern plume	2
Enallagma latifolia	black-calabash	3
Eriobotrya japonica	loquat; loquat tree	2
Erythrina herbacea	southeastern coralbean; eastern coralbean; Cherokee-bean	2
Ethretia anacua	anaqua	3
Eucalyptus botryiodes	bastard mahogany; bangalay	2
Eucalyptus camaldulensis	longbeak eucalyptus; camal eucalyptus; redgum	2
Eucalyptus camphora	eucalyptus	3
Eucalyptus cinerea	silver dollar eucalyptus	1
Eucalyptus diversifolia	eucalyptus	3
Eucalyptus globulus	bluegum eucalyptus; Tasmanian bluegum; bluegum	2
Eucalyptus gunnii	cider gumtree	1
Eucalyptus leucoxylon	white ironbark	2
Eucalyptus polyanthemos	redbox eucalyptus; redbox-gum; Australian beech; silver dollar gum	2
Eucalyptus pulchella	white peppermint	2
Eucalyptus rudis	desert gum	2
Eucalyptus sideroxylon	red ironbark	2
Eucalyptus spp.	eucalyptus; gum-tree	2
Eucalyptus tereticornis	horncap eucalyptus; gray or slaty gum	2
Euonymus atropurpureus	eastern burningbush; burningbush; eastern wahoo; strawberry-bush	2
Euonymus europaeus	European spindletree; European euonymus	2
Euonymus japonicus	Japanese euonymus; evergreen euonymus	2
Euonymus occidentalis	western burningbush; wahoo; western wahoo	2
Euonymus verrucosa	spindle tree	2
Exostema caribaeum	princewood; Caribbean princewood	2
Exothea paniculata	inkwood; butterbough	2
Fagus grandifolia	American beech; beech	2
Fagus sylvatica	European beech	2
Fatsia japonica	Japanese fatsia; Japanese aralia	3
Ficus aurea	Florida strangler fig; golden fig; strangler fig; wild fig	2
Ficus benjamina	Java fig; Java willow; Benjamin fig	3
Ficus carica	fig; common fig	2
Ficus elastica	India-rubber fig; rubber plant; India rubber tree	2
Ficus lyrata	fiddle-leaf fig	2
Firmiana platanifolia	Chinese parasoltree	2
Forestiera acuminata	swamp-privet; forestiera; common adelia; whitewood	3
Fraxinus americana	white ash; Biltmore ash; Biltmore white ash	3
Fraxinus anomala	singleleaf ash; dwarf ash	3
Fraxinus caroliniana	Carolina ash; water ash; Florida ash; pop ash; swamp ash	3
Fraxinus cuspidata	fragrant ash; flowering ash	3
Fraxinus excelsior	European ash	2
Fraxinus greggii	Gregg ash; littleleaf ash; dogleg ash	3
Fraxinus latifolia	Oregon ash	3
Fraxinus nigra	black ash; swamp ash; basket ash; brown ash; hoop ash; water ash	3
Fraxinus pennsylvanica	green ash; red ash; Darlington ash; white ash; swamp ash; water ash	3
Fraxinus profunda	pumpkin ash; red ash	3
Fraxinus quadrangulata	blue ash	3
Fraxinus spp.	ash	3

Plant List

Genus and species	Common name	Susceptibility index
Fraxinus texensis	Texas ash	3
Fraxinus uhdei	Hawaiian ash	3
Fraxinus velutina	velvet ash; Arizona ash; desert ash; Modesto ash; leatherleaf ash; smooth ash; Toumey ash	3
Garrya fremontii	Fremont silktassel; silk-tassel	3
Gaultheria shallon	salal; shallon	2
Ginkgo biloba	ginkgo; maidenhair tree	3
Gleditsia aquatica	waterlocust	3
Gleditsia texana	honeylocust; Texas honeylocust	3
Gleditsia triacanthos	honeylocust; sweet-locust; thorny-locust	3
Gordonia lasianthus	loblolly-bay; tan bay; gordonia; bay; holly-bay	2
Grevillea 'noellii'	grevillea	3
Grevillea robusta	silk-oak; silky oak	3
Guaiacum sanctum	roughbark lignumvitae; holywood lignumvitae; lignumvitae	2
Guettarda elliptica	elliptic-leaf velvetseed; Everglades velvetseed; velvetseed	2
Guettarda scabra	roughleaf velvetseed	2
Gyminda latifolia	falsebox; false boxwood; West Indies falsebox	2
Gymnanthes lucida	oysterwood; crabwood	3
Gymnocladus dioicus	Kentucky coffeetree; coffeetree	3
Hakae spp.		2
Halesia carolina	Carolina silverbell; silver bell; snowdrop-tree; opossum-wood	3
Hamamelis virginiana	witch-hazel; common witch-hazel; southern witch-hazel	1
Heteromeles arbutifolia	toyon; Christmas berry; California-holly; hollyberry	2
Hibiscus rosa-sinensis	Chinese hibiscus	2
Hibiscus tiliaceus	sea hibiscus; mahoe; tree hibiscus	2
Hippomane mancinella	manchineel	3
Ilex aquifolium	English holly	3
Ilex cassine	dahoon; dahoon holly; Alabama dahoon; Christmas-berry	3
Ilex coriacea	large gallberry; tall inkberry; gallberry; bay-gallbush	3
Ilex decidua	possumhaw; deciduous holly; winterberry	3
Ilex glabra	inkberry; gallberry	3
Ilex krugiana	tawnyberry holly; Krug holly; southern holly	3
Ilex montana	mountain winterberry; mountain holly	3
Ilex opaca	American holly; holly; white holly	3
Ilex verticillata	common winterberry; black-alder; winterberry	3
Ilex vomitoria	yaupon; cassena; Christmas-berry; evergreen holly	3
Jasminum nudiflorum	winter jasmine	3
Juglans californica	southern California walnut; California walnut; California black walnut	2
Juglans cinerea	butternut; white walnut; oilnut	2
Juglans hindsii	northern California walnut; Hinds walnut; California black walnut	2
Juglans major	Arizona walnut; Arizona black walnut	2
Juglans microcarpa	little walnut; Texas walnut; Texas black walnut; river walnut	2
Juglans nigra	black walnut; eastern black walnut; American walnut	2
Juniperus ashei	Ashe juniper; mountain-cedar; rock-cedar; post-cedar; Mexican juniper	3
Juniperus californica	California juniper	3
Juniperus coahuilensis	redberry juniper; roseberry	3
Juniperus communis	common juniper; dwarf juniper; prostrate juniper	3
Juniperus deppeana	alligator juniper; checker-bark juniper; western juniper	3
Juniperus erythrocarpa	redberry juniper; red-fruited juniper	3
Juniperus flaccida	drooping juniper; weeping juniper; Mexican drooping juniper	3
Juniperus monosperma	oneseed juniper; cherrystone juniper; West Texas juniper	3

Genus and species	Common name	Susceptibility index
Juniperus occidentalis	western juniper; Sierra juniper	3
Juniperus osteosperma	Utah juniper; bigberry juniper	3
Juniperus pinchotii	Pinchot juniper; redberry juniper	3
Juniperus scopulorum	Rocky Mountain juniper; Rocky Mountain cedar; redcedar; Colorado redcedar	3
Juniperus silicicola	southern redcedar; redcedar; sand-cedar; coast juniper	3
Juniperus virginiana	eastern redcedar; redcedar; red juniper; savin	3
Krugiodendron ferreum	leadwood; black-ironwood	2
Laguncularia racemosa	white-mangrove; white buttonwood; buttonwood	2
Larix decidua	European larch	1
Larix laricina	tamarack; eastern larch; American larch; Alaska larch; hackmatack	1
Larix lyallii	subalpine larch; alpine larch; timberline larch; tamarack	1
Larix occidentalis	western larch; hackmatack; Montana larch; mountain larch	1
Leitneria floridana	corkwood	2
Lindera benzoin	spicebush	3
Liquidambar styraciflua	sweetgum; redgum; sapgun; starleaf-gum; bilsted	1
Liriodendron tulipifera	yellow-poplar; tuliptree; tulip-poplar; white-poplar	3
Lithocarpus densiflorus	tanoak; tan oak; tanbark-oak	1
Lyonia ferruginea	tree lyonia; staggerbush; titi; rusty lyonia	2
Lyonothamnus floribundus	Lyontree; Catalina-ironwood; lyonothamnus; Santa-Cruz-ironwood	2
Lysiloma bahamensis	Bahama lysiloma	2
Maclura pomifera	Osage-orange; bodark; bodock; bowwood; hedge-apple; horse-apple	3
Magnolia acuminata	cucumbertree; cucumber magnolia; mountain magnolia	3
Magnolia ashei	Ashe magnolia; sandhill magnolia	3
Magnolia fraseri	Fraser magnolia; mountain magnolia; earleaf cucumbertree	3
Magnolia grandiflora	southern magnolia; evergreen magnolia; bull-bay; big-laurel	3
Magnolia macrophylla	bigleaf magnolia; umbrella-tree; large-leaf cucumbertree	3
Magnolia pyramidata	pyramid magnolia; southern cucumbertree; mountain magnolia	3
Magnolia soulangeana	saucer magnolia; rustica rubra	3
Magnolia tripetala	umbrella magnolia; umbrella-tree; elkwood	3
Magnolia virginiana	sweetbay; swampbay; southern sweetbay; laurel magnolia	3
Malus angustifolia	southern crab apple; narrowleaf crab apple; wild crab apple	1
Malus coronaria	sweet crab apple; American crab apple; wild crab	1
Malus diversifolia	Oregon crab apple; Pacific crab apple; western crab apple; wild crab apple	1
Malus glabrata	sweet crab apple; Biltmore crab apple; wild crab	1
Malus ioensis	prairie crab apple; wild crab apple; Iowa crab	1
Malus spp.	apple	1
Melaleuca decussata	lilac melaleuca	1
Melaleuca quinquenervia	cajeput-tree; punktree; bottlebrush	2
Melia azedarach	chinaberry; umbrella chinaberry; chinatree; pride-of-India	2
Mespilus germanica	medlar; showy mespilus; European medlar	2
Metasequoia glyptostroboides	dawn redwood	2
Metopium toxiferum	Florida poisontree; poisonwood; West Indies poisontree	1
Morus alba	white mulberry; silkworm mulberry; Russian mulberry; weeping mulberry	3
Morus microphylla	Texan mulberry; Texas mulberry; Mexican mulberry; mountain mulberry	3
Morus nigra	black mulberry	3
Morus rubra	red mulberry; moral	3
Morus tartarica	Tartarian mulberry	2
Myrica californica	Pacific bayberry; California bayberry; Pacific waxmyrtle; western waxmyrtle; California waxmyrtle	2
Myrica cerifera	southern bayberry; southern waxmyrtle; bayberry; candleberry	2
Nyssa aquatica	water tupelo; tupelo-gum; cotton-gum; sourgum	3

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Genus and species	Common name	Susceptibility index
Nyssa ogeche	Ogeechee tupelo; sour tupelo-gum; Ogeechee-lime; sour tupelo	3
Nyssa sylvatica	black tupelo; blackgum; sourgum; pepperidge; tupelo	3
Nyssa sylvatica var. *biflora*	swamp tupelo, blackgum; swamp blackgum	3
Olea europaea	olive; common olive	3
Olneya tesota	tesota; desert ironwood; Arizona-ironwood	2
Osmanthus americana	devilwood; wild-olive	3
Ostrya knowltonii	Knowlton hophornbeam; western hophornbeam; wolf hophornbeam	2
Ostrya virginiana	eastern hophornbeam; hophornbeam; American hophornbeam; hornbeam; leverwood	1
Oxydendrum arboreum	sourwood; sorrel-tree; lily-of-the-valley-tree	2
Parkinsonia aculeata	Jerusalem-thorn; horsebean; Mexican paloverde	2
Paulownia tomentosa	royal paulownia; empress-tree; princess-tree; paulownia	3
Paurotis wrightii	paurotis-palm; paurotis	3
Persea americana	avocado; zutano avocado; alligator-pear	2
Persea borbonia	redbay; shorebay	2
Photinia arbutifolia	toyon; Christmas berry	2
Photinia glabra	Japanese photinia	2
Photinia serrulata	Chinese photinia; Chinese medlar	2
Photinia spp.	toyon; photinia	3
Picea abies	Norway spruce	2
Picea breweriana	Brewer spruce; weeping spruce	2
Picea englemannii	Engelmann spruce; Columbian spruce; mountain spruce; silver spruce; white spruce	2
Picea glauca	white spruce; skunk spruce; Canadian spruce; cat spruce	2
Picea glauca var. *conica*	dwarf Alberta spruce; dwarf white spruce	2
Picea mariana	black spruce; bog spruce; swamp spruce; shortleaf black spruce	2
Picea polita	tigertail spruce	2
Picea pungens	blue spruce; Colorado blue spruce; Colorado spruce; silver spruce	2
Picea rubens	red spruce; yellow spruce; West Virginia spruce; eastern spruce	2
Picea sitchensis	Sitka spruce; coast spruce; tideland spruce; yellow spruce	2
Picea spp.	spruce	2
Picramnia pentandra	bitterbush; Florida bitterbush	2
Pinckneya pubens	pinckneya; fevertree; Georgia-bark; fever-bark	2
Pinus albicaulis	whitebark pine; scrub pine; white pine	2
Pinus aristata	bristlecone pine; hickory pine; foxtail pine	2
Pinus attenuata	knobcone pine	2
Pinus balfouriana	foxtail pine	2
Pinus banksiana	jack pine; scrub pine; gray pine; black pine; Banksian pine	2
Pinus cembroides	Mexican pinyon; nut pine; Mexican stone pine	2
Pinus clausa	sand pine; scrub pine; spruce pine	2
Pinus contorta	lodgepole pine; shore pine; beach pine	2
Pinus coulteri	Coulter pine; bigcone pine; pitch pine	2
Pinus discolor	border pinyon	2
Pinus echinata	shortleaf pine; shortleaf yellow pine; yellow pine	2
Pinus edulis	pinyon; two-leaf pinyon; two-needle pinyon	2
Pinus elliottii	slash pine; yellow slash pine; swamp pine; pitch pine	2
Pinus engelmannii	Apache pine; Arizona longleaf pine	2
Pinus flexlis	limber pine; white pine, Rocky Mountain whitepine	2
Pinus glabra	spruce pine; cedar pine; Walter pine; bottom white pine	2
Pinus halepensis	Aleppo pine	2
Pinus jeffreyi	Jeffrey pine; western yellow pine; bull pine; black pine; ponderosa pine	2

Genus and species	Common name	Susceptibility index
Pinus lambertiana	sugar pine; California sugar pine	2
Pinus leiophylla var. *chihuahuana*	Chihuahua pine; yellow pine	2
Pinus longaeva	intermountain bristlecone pine	2
Pinus monophylla	singleleaf pinyon; pinyon; nut pine	2
Pinus monticola	western white pine; mountain white pine; Idaho white pine; silver pine	2
Pinus mugo	mugo pine; mountain pine; Swiss mountain pine	2
Pinus muricata	bishop pine; prickle-cone pine; Santa Cruz Island pine	2
Pinus nigra	Austrian pine; European black pine	2
Pinus palustris	longleaf pine; swamp pine; longleaf yellow pine; southern yellow pine	3
Pinus pinea	Italian stone pine	3
Pinus ponderosa	ponderosa pine; western yellow pine; yellow pine	2
Pinus ponderosa var. *arizonica*	Arizona pine; Arizona ponderosa pine; yellow pine	2
Pinus pungens	Table Mountain pine; mountain pine; hickory pine	2
Pinus quadrifolia	Parry pinyon; four-needle pinyon; nut pine	2
Pinus radiata	Monterey pine; insignis pine	2
Pinus resinosa	red pine; Norway pine	2
Pinus rigida	pitch pine	3
Pinus sabiniana	Digger pine; bull pine; gray pine	2
Pinus serotina	pond pine; marsh pine; pocosin pine	2
Pinus spp.	pine	2
Pinus strobiformis	southwestern white pine; Mexican white pine; border white pine	2
Pinus strobus	eastern white pine; northern white pine; white pine	2
Pinus sylvestris	Scotch pine; Scots pine	2
Pinus taeda	loblolly pine; oldfield pine; shortleaf pine	2
Pinus thunbergiana	Japanese black pine	3
Pinus torreyana	Torrey pine; Del Mar pine; Soledad pine	2
Pinus virginiana	Virginia pine; Virginia scrub pine; spruce pine; Jersey pine; scrub pine; poverty pine	2
Pinus washoensis	Washoe pine	2
Piscidia piscipula	Florida fishpoison-tree; Jamaica-dogwood; Florida fishfuddletree	2
Pistacia texana	Texas pistache; American pistachio; wild pistachio	1
Pistacia vera	pistachio	1
Planera aquatica	water-elm; planertree	2
Platanus occidentalis	sycamore; American sycamore; American planetree; buttonwood	3
Platanus orientalis	Oriental planetree	2
Platanus racemosa	California sycamore; western sycamore; California planetree	3
Platanus wrightii	Arizona sycamore; Arizona planetree	3
Populus alba	white poplar; silver poplar	2
Populus angustifolia	narrowleaf cottonwood; black cottonwood; mountain cottonwood; narrowleaf poplar	1
Populus balsamifera	balsam poplar; balm; balm-of-Gilead; bam; tacamahac	1
Populus deltoides	eastern cottonwood; eastern poplar; southern cottonwood	2
Populus fremontii	Fremont cottonwood; cottonwood	2
Populus grandidentata	bigtooth aspen; largetoothed aspen; aspen; poplar; popple	1
Populus heterophylla	swamp cottonwood; black cottonwood; river cottonwood	1
Populus nigra var. *italica*	Lombardy poplar	1
Populus palmeri	eastern cottonwood; eastern poplar; Palmer cottonwood	1
Populus sargentii	plains cottonwood; great plains cottonwood; sargent cottonwood	1
Populus spp.	cottonwood; poplar	1
Populus tremuloides	quaking aspen; trembling aspen; golden aspen	1

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Genus and species	Common name	Susceptibility index
Populus trichocarpa	black cottonwood; western balsam poplar; cottonwood; balsam cottonwood	1
Populus wislizenii	Rio Grande cottonwood; valley cottonwood	1
Prosopis juliflora	honeylocust; mesquite; algaroba	2
Prosopis pubescens	screwbean mesquite; screwbean	2
Prunus alleghaniensis	Allegheny plum; sloe plum; sloe; Allegheny sloe; northern sloe	2
Prunus americana	American plum; wild plum; red plum; river plum; yellow plum	2
Prunus angustifolia	Chickasaw plum; sand plum	2
Prunus avium	mazzard; common sweet cherry; English cherry	2
Prunus caroliniana	Carolina laurelcherry; laurel cherry; cherry-laurel	2
Prunus domestica	garden plum; plum; Damson plum	2
Prunus emarginata	bitter cherry; quinine cherry; wild cherry	2
Prunus fremontii	desert apricot	2
Prunus glandulosa	flowering almond; dwarf flowing almond; almond cherry; wild peach	2
Prunus hortulana	hortulan plum; wild goose plum; Miner plum; wild plum	2
Prunus japonica	Japanese plum	2
Prunus laurocerasus	cherry laurel; English laurel	2
Prunus lyonii	Catalina cherry	2
Prunus maritima	beach plum	2
Prunus mexicana	Mexican plum; bigtree plum; inch plum	2
Prunus munsoniana	wildgoose plum; Munson plum	2
Prunus myrtifolia	West Indies cherry; myrtle laurel cherry; laurelcherry	2
Prunus nigra	Canada plum; red plum; horse plum; wild plum	2
Prunus padus	European bird-cherry; black serviceberry	2
Prunus pensylvanica	pin cherry; wild red cherry; fire cherry; northern pin cherry; pigeon cherry; bird cherry	3
Prunus persica	peach; nectarine; heavenly white nectarine; Tilton apricot	2
Prunus pissardi	purple-leaved prune	2
Prunus pumila	sand cherry	2
Prunus serotina	black cherry; wild black cherry; rum cherry; mountain black cherry	2
Prunus spinosa	sloe; blackthorn	2
Prunus spp.	cherry; plum	2
Prunus subcordata	Klamath plum; Sierra plum; Pacific plum; western plum; wild plum	2
Prunus umbellata	flatwoods plum; black sloe; hog plum; sloe	2
Prunus virginiana	chokecherry; common chokecherry; black chokecherry; California chokecherry	2
Pseudophoenix sargentii	buccaneer-palm; Florida cherrypalm; Sargent cherrypalm	3
Pseudotsuga macrocarpa	bigcone Douglas-fir; bigcone-spruce; hemlock	2
Pseudotsuga menziesii	Douglas-fir; red-fir; Oregon-pine; Douglas-spruce	2
Psidium guajava	guava; common guava; guayaba	2
Ptelea trifoliata	hoptree; common hoptree; wafer-ash	2
Punica granatum	pomegranate	2
Pyracantha coccinea	scarlet firethorn; everlasting thorn; fire thorn	2
Pyrus angustifolia	narrowleaf crab apple	1
Pyrus arbutifolia	red chokecherry; red chokeberry; chokeberry	2
Pyrus communis	pear; common pear	2
Pyrus malus	wild apple; common apple	1
Quercus agrifolia	coast live oak; California live oak	1
Quercus alba	white oak; stave oak	1
Quercus arizonica	Arizona white oak; Arizona oak	1
Quercus austrina	Durand oak; Durand white oak; bluff oak	1
Quercus bicolor	swamp white oak	1
Quercus chapmanii	Chapman oak; Chapman white oak; scrub oak	1

Genus and species	Common name	Susceptibility index
Quercus chrysolepis	canyon live oak; California live oak; canyon oak; goldcup oak; live oak; maul oak	1
Quercus cinerea	bluejack oak	1
Quercus coccinea	scarlet oak; black oak; Spanish oak	1
Quercus douglasii	blue oak; California blue oak; iron oak; mountain white oak; mountain oak	1
Quercus durandii	Durand oak; Durand white oak; bluff oak; white oak	1
Quercus ellipsoidalis	northern pin oak; jack oak; black oak; Hill oak	1
Quercus emoryi	Emory oak; black oak; blackjack oak	1
Quercus engelmannii	Engelmann oak; evergreen white oak; mesa oak; Engelmann spruce	1
Quercus falcata	southern red oak; Spanish oak; water oak; red oak	1
Quercus gambelii	Gambel oak; Rocky Mountain white oak; Utah white oak; white oak	1
Quercus garryana	Oregon white oak; Oregon oak; Garry oak; post oak; white oak; Brewer oak; shin oak	1
Quercus grisea	gray oak; Arizona gray oak	1
Quercus hemisphaerica	laurel oak; Darlington oak	1
Quercus hypoleucoides	silverleaf oak; white-leaf oak	1
Quercus ilicifolia	bear oak; scrub oak	1
Quercus imbricaria	shingle oak; laurel oak	1
Quercus incana	bluejack oak; cinnamon oak; sandjack; bluejack; shin oak; turkey oak	1
Quercus kelloggii	California black oak; black oak; Kellogg oak	1
Quercus laevis	turkey oak; Catesby oak; scrub oak	1
Quercus laurifolia	laurel oak; Darlington oak; diamond-leaf oak; swamp laurel oak	1
Quercus lobata	valley oak; California white oak; valley white oak; water oak	1
Quercus lyrata	overcup oak; swamp post oak; swamp white oak; water white oak	1
Quercus macrocarpa	bur oak; mossy cup oak; blue oak; mossy-overcup oak; scrub oak	1
Quercus margaretta	sand post oak; small post oak; dwarf post oak; post oak	1
Quercus marilandica	blackjack oak; blackjack; barren oak; black oak; jack oak	1
Quercus michauxii	swamp chestnut oak; basket oak; cow oak	1
Quercus muehlenbergii	chinkapin oak; yellow chestnut oak; chestnut oak; rock chestnut oak	1
Quercus myrtifolia	myrtle oak; scrub oak	1
Quercus nigra	water oak; possum oak; spotted oak	1
Quercus nuttallii	Nuttall oak; red oak; Red River oak; pin oak	1
Quercus oblongifolia	Mexican blue oak	1
Quercus oglethorpensis	Oglethorpe oak	1
Quercus pagoda	cherrybark oak; swamp red oak; bottomland red oak	1
Quercus palustris	pin oak; swamp oak; water oak; swamp Spanish oak; Spanish oak	1
Quercus phellos	willow oak; pin oak; peach oak; swamp willow oak	1
Quercus prinus	chestnut oak; basket oak; rock chestnut oak; rock oak; tanbark oak	1
Quercus rubra	northern red oak; red oak; common red oak; gray oak; eastern red oak; mountain red oak	1
Quercus shumardii	Shumard oak; Shumard red oak; spotted oak; Schneck oak; Schneck red oak; southern red oak	1
Quercus spp.	oak	1
Quercus stellata	post oak; iron oak	1
Quercus suber	cork oak	1
Quercus undulata	Rocky Mountain shin oak; wavyleaf oak	1
Quercus velutina	black oak; yellow oak; quercitron oak; yellow-bark oak; smooth-bark oak	1
Quercus virginiana	live oak; Virginia live oak	1
Quercus wislizenii	interior live oak; highland live oak; Sierra live oak	1
Rapanea guianensis	Guiana rapanea	2
Reynosia septentrionalis	darling-plum; red-ironwood	2
Rhamnus californica	California buckthorn; coffeeberry; California coffeeberry; pigeonberry	3
Rhamnus caroliniana	Carolina buckthorn; Indian-cherry; yellow buckthorn; tree buckthorn; yellowwood	3
Rhamnus cathartica	European buckthorn; common buckthorn; European waythorn	3

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Genus and species	Common name	Susceptibility index
Rhamnus frangula	glossy buckthorn; alder buckthorn	3
Rhamnus purshiana	cascara buckthorn; cascara; cascara sagrada; bearberry; chittam; coffeetree	2
Rhizophora mangle	mangrove; red mangrove	2
Rhus copallina	shining sumac; dwarf sumac; winged sumac; wing-rib sumac; flameleaf sumac	2
Rhus corallina	mountain sumac	1
Rhus cotinus	smoketree; common smoketree	2
Rhus glabra	smooth sumac; scarlet sumac; common sumac; Rocky Mountain sumac; red sumac	1
Rhus integrifolia	lemonade sumac; sourberry; lemonade-berry; mahogany sumac	2
Rhus typhina	staghorn sumac; velvet sumac	1
Ribes uva-crispa	English gooseberry	2
Robinia neomexicana	New Mexico locust; New Mexican locust; southwestern locust	3
Robinia pseudoacacia	black locust; common locust; yellow locust; white locust	3
Robinia spp.	locust	2
Robinia viscosa	clammy locust	3
Rosa bracteata	Macartney rose	2
Rosa eglanteria	sweetbriar; sweetbriar rose	2
Rosa setigera	prairie rose; climbing prairie rose	2
Rosa spp.	rose	1
Roystonea elata	Florida royalpalm; Cuban royalpalm; royalpalm	3
Sabal palmetto	cabbage palmetto; common palmetto; Carolina palmetto; palmetto; cabbage-palm	3
Salix alaxensis	feltleaf willow	1
Salix alba	white willow; European white willow	1
Salix alba var. *tristis*	golden weeping willow	1
Salix amygdaloides	peachleaf willow; peachleaved willow; almond willow; peach willow; southwestern peach willow	1
Salix babylonica	weeping willow; Babylon weeping willow; Napolean willow	2
Salix bebbiana	Bebb willow; beak willow; long-beak willow; diamond willow	1
Salix bonplandiana	Bonpland willow; Toumey willow; red willow; polished willow	1
Salix caroliniana	Coastal Plain willow; Ward willow; southern willow; Harbison willow	1
Salix cordata	heartleaf willow; heart-leaved willow	1
Salix discolor	pussy willow; glaucous willow; silvery pussy willow	1
Salix eriocephala	pussy willow	1
Salix fragilis	crack willow; brittle willow; snap willow	1
Salix hookerana	Hooker willow; coast willow; Yakutat willow; bigleaf willow	1
Salix interior	sandbar willow; coyote willow; acequia willow; basket willow; gray willow; sandbar willow	1
Salix laevigata	Bondpland willow; red willow; Toumey willow; polished willow	1
Salix lasiandra	Pacific willow; whiplash willow; black willow; red willow; western black willow; yellow willow	1
Salix lasiolepis	arroyo willow; white willow	1
Salix lucida	shining willow; shiny willow	1
Salix mackenzieana	Mackenzie willow	1
Salix nigra	black willow; swamp willow; Goodding willow; western black willow; Dudley willow	1
Salix pentandra	laurel willow; bay willow; bayleaf willow	2
Salix scouleriana	Scouler willow; fire willow; black willow; mountain willow; Nuttall willow	1
Salix spp.	willow	1
Salix taxifolia	yewleaf willow; yew willow	1
Salix viminalis	basket willow; osier; common osier; silky osier	1
Sambucus callicarpa	Pacific red elder; Pacific elder; coast red elder; redberry elder; red elderberry	2
Sambucus canadensis	American elder; common elderberry; common elder; blackberry elder	3
Sapindus drummondii	western soapberry; wild chinatree; cherioni	2
Sapindus marginatus	wingleaf soapberry; Florida soapberry	2
Sapindus saponaria	wingleaf soapberry; Florida soapberry; southern soapberry; Mexican soapberry; wild chinatree	2

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Sapium sebiferum	tallowtree; Chinese tallowtree	3
Sassafras albidum	sassafras; white sassafras	2
Schinus molle	peppertree; California peppertree; Peru peppertree	1
Sequoia sempervirens	redwood; coast redwood; California redwood	2
Sequoiadendron giganteum	giant sequoia; sequoia; bigtree; Sierra redwood	2
Sideroxylon foetidissimum	false-mastic; mastic; wild-mastic; wild-olive	2
Simarouba glauca	paradise-tree; bitterwood	2
Sophora affinis	Texas sophora; coralbean; pink sophora; Eves-necklace	3
Sophora japonica	Japanese pagoda-tree	3
Sophora secundiflora	mescalbean; frigolito; coralbean; Texas-mountain-laurel	2
Sorbus americana	American mountain-ash; mountain-ash; roundwood	1
Sorbus aucuparia	European mountain-ash; Rowan-tree	1
Spiraea bumalda	Bumalda spirea; spirea	3
Stewartia koreana	Korean stewartia; stewartia	3
Stewartia ovata	mountain stewartia; mountain-camellia; angel-fruit stewartia	2
Swietenia mahagoni	West Indies mahogany; mahogany	2
Symphoricarpos albus	snowberry; waxberry; common snowberry	3
Symplocos tinctoria	sweetleaf; horse-sugar; common sweetleaf; yellowwood	2
Tamarix parviflora	small-flower tamarisk	2
Taxodium distichum	baldcypress	3
Taxodium mucronatum	Montezuma baldcypress; Mexican cyress	3
Taxus brevifolia	Pacific yew; western yew	3
Taxus floridana	Florida yew	3
Thrinax microcarpa	key thatchpalm; silvertop palmetto; prickly thatch; brittle thatch; brittle thatch palm	3
Thrinax parviflora	Jamaica thatchpalm	3
Thuja occidentalis	northern white-cedar; white-cedar; eastern arborvitae; American arborvitae; eastern white-cedar	3
Thuja orientalis	oriental arborvitae; Chinese arborvitae	3
Thuja plicata	western redcedar; giant western arborvitae; Pacific redcedar; giant-cedar; arborvitae; canoe-cedar	3
Tilia americana	American basswood; American linden; basswood	1
Tilia caroliniana	Carolina basswood; Florida basswood; basswood; Carolina linden; Florida linden	1
Tilia cordata	littleleaf linden; small-leaved linden; small-leaved European linden	1
Tilia europaea	European linden; common linden	1
Tilia floridana	Florida basswood; Carolina basswood	1
Tilia heterophylla	white basswood; beetree; linden; beetree linden	1
Torreya californica	California torreya; California-nutmeg	3
Torreya taxifolia	Florida torreya; stinking-cedar	3
Torrubia longifolia	longleaf blolly; Brace blolly; roundleaf blolly; beeftree; beefwood	2
Toxicodendron vernix	poison-sumac; poison-dogwood; poison-elder; thunderwood	1
Trema micrantha	Florida trema	2
Tsuga canadensis	eastern hemlock; Canadian hemlock; Canada hemlock; hemlock spruce; common hemlock	2
Tsuga caroliniana	Carolina hemlock	2
Tsuga heterophylla	western hemlock; Pacific hemlock; west coast hemlock	2
Tsuga mertensiana	mountain hemlock; black hemlock; alpine hemlock; hemlock spruce	2
Ulmus alata	winged elm; wahoo elm; cork elm; wahoo	2
Ulmus americana	American elm; white elm; water elm; soft elm; Florida elm	2
Ulmus campestris	English elm; European elm	2
Ulmus crassifolia	cedar elm; basket elm; red elm; southern rock elm	2
Ulmus glabra	Scotch elm; wych elm	2
Ulmus montana	Scotch elm	2
Ulmus parvifolia	Chinese elm; lacebark	2

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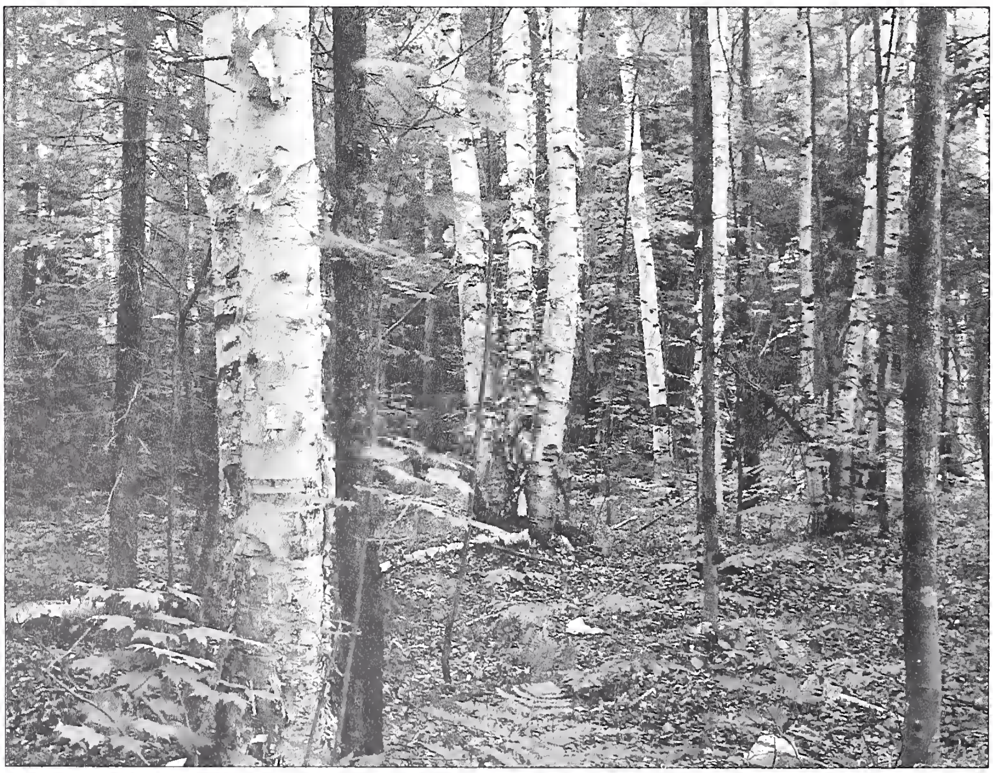
Genus and species	Common name	Susceptibility index
Ulmus pumila	Siberian elm; Asiatic elm; dwarf Asiatic elm; Pekin elm	2
Ulmus racemosa	rock elm; cork elm	2
Ulmus rubra	slippery elm; red elm; gray elm; soft elm	3
Ulmus serotina	September elm; red elm	2
Ulmus spp.	elm	2
Ulmus thomasii	rock elm; cork elm	2
Umbellularia californica	California-laurel; California-bay; Oregon-myrtle; Pacific-myrtle; pepperwood; spice-tree	3
Vauquelinia californica	Torrey vauquelinia; Arizona-rosewood	2
Veitchia merrillii	Manila palm	3
Viburnum acerifolium	mapleleaf viburnum; dockmackie; maple-leaved arrowwood	3
Viburnum ellipticum	western blackhaw; oval-leafed virburnum	2
Viburnum lantana	wayfaringtree	2
Viburnum lentago	nannyberry; sheepberry; sweet viburnum; blackhaw; sheepberry	3
Viburnum opulus	European cranberrybush; highbush cranberry; cranberry tree	3
Viburnum prunifolium	blackhaw; stagbush; sweethaw	2
Viburnum pubescens	downy viburnum; hairy nannyberry; downy arrowwood	2
Viburnum rhytidophyllum	leatherleaf viburnum	2
Viburnum spp.	viburnum; wayfaringtree	3
Viburnum tomentosum	doublefile viburnum	3
Washingtonia filifera	California washingtonia; California-palm; fanpalm; California fanpalm; desert-palm	3
Ximenia americana	tallowwood; hogplum	3
Zanthoxylum americanum	common prickly-ash; toothache-tree; northern prickly-ash; prickly-ash	2
Zanthoxylum clava-herculis	Hercules-club; pepperbark; southern prickly-ash; toothache-tree; tingle-tongue	2
Zanthoxylum fagara	lime prickly-ash; wild-lime-tree; wild-lime	2
Zanthoxylum flavum	West Indies satinwood; yellowheart; satinwood; yellowwood	2



Susceptibility of birches (Betula *spp.) to the gypsy moth varies.*

Appendix E

History of the Gypsy Moth and Control Efforts

Spraying in 1891

Appendix E

History of the Gypsy Moth and Control Efforts

Contents

This appendix describes the spread of the gypsy moth in the United States from 1869 to 1995, along with the progression of efforts to control it (*fig. E-1*).

1869 to 1910: Biological Controls Fail

When the European strain of the gypsy moth first escaped in Medford, Massachusetts, around 1869, it was considered a curiosity. Public perception of the gypsy moth as a problem came two decades later when the gypsy moth population exploded. Citizens soon saw the consequences of allowing the moths to go uncontrolled (Dunlap 1980, p. 118):

> In the summer of 1889 it [the gypsy moth] threatened to overrun Medford, Massachusetts. The startled townspeople discovered caterpillars in astounding numbers, swarming through trees, eating leaves, and coating the ground below with droppings. People swept insects from their sidewalks, porches, and clothes; carried umbrellas to ward off droppings and falling caterpillars; and even wore face nets. The town, unable to deal with the situation, appealed to the state for aid. The striking nature of the infestation—and its occurrence in an urban area—brought quick response from the commonwealth, and an ambitious effort to deal with the pest was begun.

Control methods included destroying egg masses, burning infested trees and shrubs, banding trees to trap caterpillars, or spraying with insecticides. Paris green was the first gypsy moth insecticide used. It was replaced with lead arsenate in 1893 (McManus and McIntyre 1981).

Figure E-1. The gypsy moth has continued its relentless spread to the north, south, and west of Medford, Massachusetts, where it was introduced around 1869. The rate of spread averaged 2 to 6 miles (3 to 10 km) per year before 1966, but accelerated to about 13 miles (21 km) per year between 1966 and 1990.

Massachusetts' efforts to eradicate the gypsy moth were considered so successful that the project was abandoned in 1900. In 1906, after the second irruption of the gypsy moth, the Federal government stepped in to fight the nonnative insect. By then, it had spread so far that eradication was not possible. Entomologists with what was then the USDA Bureau of Entomology began to study the life cycle of the insect, as well as to figure out what natural enemies from Europe could be used against it. Natural enemies were introduced, but these biological control efforts failed to stop the moths. Funding was reduced on basic research activities (Dunlap 1980, p. 121):

> Biological control proved to be much more difficult than either the scientists or the public had anticipated. Importing and establishing the moth's natural enemies was

neither simple nor inexpensive. Some of the parasites immediately died in the new environment, others refused to breed, and still others vanished without a trace when released. Some survivors were found to be preying on the moth, but with no noticeable effect on its population.

1911 to 1939: Chemical Insecticides Gain Favor

The Bureau of Entomology issued a report in 1911 stating that, to effectively use biological controls to control the gypsy moth in the United States (Dunlap 1980, p. 121),

> . . . all fifty of the moth's known European predators [would have to be imported and established], which would require long-term studies of the ecology of the moth and its enemies.

It did not take long for the public, as well as scientists and politicians, to see that using biological controls successfully would take much more research and funding (Dunlap 1980, p. 123):

> With the end of hope that natural enemies would control the moth, both state and federal workers fell back on a piecemeal approach. They sought to reduce damage in highly visible and economically important areas—roadsides and towns.

The gypsy moth spread throughout New England and by 1914 the generally infested area included the southern half of New Hampshire, Rhode Island, eastern Connecticut, southern Vermont, and the eastern half of Massachusetts (McManus and McIntyre 1981). The favored control method became the use of chemical insecticides (Dunlap 1980, p. 123-124):

> Their popularity was due in part to . . . the public's desire for an immediate [visible] solution to [gypsy moth] problems and its reluctance to invest in long-term research that did not promise a certain or immediate return. Chemicals . . . gave immediate and gratifying visible results. Best of all, they could be used by individual landowners or towns without regard to coordination with other people or jurisdictions. . . .
>
> In forest spraying, however, chemicals proved ineffective. Better equipment and sprays now made roadside and urban spraying practical . . . [while] skyrockets and aerial bombs proved interesting but impractical. Spraying from planes or autogiros [early helicopters] seemed promising . . . [but] the hazards of tall trees, crosswinds, and irregular terrain made spraying difficult, but the most important factor was economic: American forests had too low a return per acre to justify the expense and repeated spraying that were necessary to control the moth.
>
> The same economic calculations also doomed another, ecological, control method [that of silviculture] . . . replacing stands of susceptible or favored food species with those that were more resistant to the moth's attacks or less palatable. Unfortunately, this approach, like extensive forest spraying, presupposed a relatively high return per acre, and nothing came of it.

In 1923 the U.S. Department of Agriculture (USDA), in cooperation with the infested States and Canada, established a barrier zone from the Canadian border along the Hudson River and Champlain Valleys to Long Island. Gypsy moth infestations east of this barrier were to be treated by the States, while infestations to the west were to be eradicated. The first major infestation west of the barrier zone occurred in Pennsylvania in 1932. Six years later, the New England hurricane of September 21, 1938, spread the gypsy moth for hundreds of miles into new territory. By the next year the barrier zone had become generally infested.

1940 to 1957: DDT Gets Widespread Use

New insecticide controls were considered and experimented with both before and during World War II. In the 1940's, cryolite was used experimentally as a gypsy moth insecticide in Pennsylvania but was ineffective. The most promising new insecticide was a synthetic organic chemical, dichloro-diphenyl-trichloroethane (DDT) (Dunlap 1980, p. 124):

> Even before the end of World War II, American and Canadian scientists were using experimental lots of the new chemical for aerial spraying on northern forests to test DDT against the gypsy moth and the spruce budworm. The results were astounding. Less than a pound of DDT per acre killed almost all the caterpillars, but it did not, apparently, cause any significant damage to wildlife.

DDT was also used experimentally in Pennsylvania, and the gypsy moth was considered eradicated in the State by 1948. Undetected infestations, however, led to further outbreaks and continued spread (Nichols 1961).

Gypsy moth infestations proliferated in the 1950's, and another barrier zone was set up through the Adirondack plateau in an attempt to prevent spread to the south and west. By the mid-1950's, however, the insect was detected in previously uninfested areas in New Jersey, New York, Pennsylvania, and Michigan. A major Federal effort was initiated to eradicate the gypsy moth (Dunlap 1980, p. 124-125):

> The first phase, to begin in the spring of 1957, involved aerial spraying to eliminate outlying populations of the moth in New York, Pennsylvania, and Michigan. If these were successful, a second phase would follow, wiping out the main body in New England. . . . The moth's periodic outbreaks caused serious but local damage, and there was no urgent demand to quell the latest one. The only clear rationale was the availability of DDT . . .
>
> Spraying began in April 1957 and lasted until June, covering more than 3 million acres in the Northeast with DDT. It brought a storm of criticism from the populace, from scientists, and from local and state officials. Some objected to the nuisance—cars dotted with scum or pools covered with layers of oil [from the carrier used to spray the DDT]. Other effects were more serious. Dairy farmers complained that DDT fell on their pastures and passed into the milk, contaminating it. Organic farmers on Long Island also protested, for the sprays rendered their crops unsuitable for the special markets. . . . The program also met legal challenge, the first serious environmental litigation against a pest control program . . . it [proved to be] too controversial for officials and bureaus whose budgets depended on public goodwill.

1958 to the Mid 1980's: Safer Treatments Needed

During its use, DDT was applied to over 12 million acres (4.9 million ha) of forest in nine northeastern States and Michigan for gypsy moth control (U.S. EPA 1975). Questions concerning the nontarget effects of DDT led to its being replaced with the carbamate, carbaryl (Sevin), in the late 1950's. An end to the use of DDT began after publication of Rachel Carson's book, *Silent Spring*, in 1962. The Forest Service stopped using DDT in its Eastern Region before it became directly involved in gypsy moth suppression and eradication (Paananen and others 1987). Although carbaryl was considered to be safer than DDT, in certain formulations it was shown to be toxic to honeybees (USDA 1985).

Between 1970 and 1981 suppression of gypsy moth outbreaks was accomplished with aerial applications of broad spectrum insecticides, including carbaryl, and the organophosphates trichlorfon (Dylox) and—to a lesser degree—acephate (Orthene). Being broad spectrum nerve poisons, these insecticides killed not only gypsy moth caterpillars, but many other immature and adult insects in the treatment areas as well.

In the 1970's research efforts to find effective means of gypsy moth control were initiated. This research included the use of the gypsy moth nucleopolyhedrosis virus (NPV) and *Bacillus thuringiensis* var. *kurstaki* (*B.t.k.*) as biological control agents. Gypchek, an insecticide made from NPV, was registered in 1978. The insect growth regulator diflubenzuron (Dimilin) was also registered in 1978, and offered an attractive alternative with fewer effects on nontarget organisms than other chemical insecticides.

Also in 1971, the USDA increased exploration for foreign parasites and predators of the gypsy moth, and began funding research on a synthetic pheromone (disparlure) and on gypsy moth population dynamics and environmental effects (McManus and McIntyre 1981). This and other research has led to development of noninsecticidal methods, such as mass trapping, mating disruption, and the sterile insect technique, for use in gypsy moth projects.

Attempts to completely eliminate the gypsy moth from the United States were abandoned in the 1970's, and gypsy moth management took a two-phase approach: suppression of outbreaks in the generally infested area and eradication of isolated infestations that resulted from inadvertent transport of the insect by people into the uninfested area.

By the middle 1980's diflubenzuron and *B.t.k.* had largely replaced carbaryl and trichlorfon as the insecticides of choice in cooperative gypsy moth suppression projects. Trichlorfon was last used in cooperative suppression projects in 1984, and carbaryl was last used in 1987 (USDA Forest Service 1994d). Broad spectrum chemical insecticides were last used in cooperative eradication projects in 1989 (USDA APHIS 1992).

Mid 1980's to the Present: Integrated Pest Management Is Adopted

Integrated pest management (IPM) became the standard approach to gypsy moth suppression and eradication in the 1980's and is still used today. This approach includes the use of various management practices, including the application of chemical and biological insecticides, as well as noninsecticidal methods.

Up to this point, controls had been used against high density populations of the gypsy moth in relatively small treatment blocks. Three successive studies began attempts to keep low density populations from expanding over geographic areas of increasing size.

During 1983-1987 the Forest Service led Federal, State, and county agencies in a study of IPM over a five-county area in Maryland (Reardon and others 1993). Advances were made in the operational use of controls that are specific to the gypsy moth: a better formulation and application parameters for the nucleopolyhedrosis virus (Gypchek), and the first release of sterile eggs. Geographic information system computer technologies were used to collect and handle data.

The second study was initiated in 1987 in 38 counties along the Appalachian Mountains in Virginia and West Virginia (USDA Forest Service 1989). Researchers succeeded in minimizing damage in the project area, reducing adverse environmental effects using gypsy-moth-specific treatments in an IPM approach, and demonstrated that slowing the spread of the gypsy moth is technically feasible. The study concluded in 1992 (USDA Forest Service 1994e).

The third study, a 5-year pilot project started in 1992, is developing the same concepts and methods over four states—Virginia, West Virginia, North Carolina, and Michigan—to determine whether it is operationally and economically feasible to slow the spread of the gypsy moth across the country.

As a continuation of these three field studies, development and improvement of methods for IPM continue on a national scale for the gypsy moth—and for all major forest pests—at the Forest Service's National Center for Forest Health Management, and at other units of the Forest Service, APHIS, Agricultural Research Service, and Cooperative State Research, Education, and Extension Service.

1991 to the Present: An Additional Concern

In 1991 the Asian strain of the gypsy moth was found for the first time in the United States. Because females have the ability to fly, the Asian strain could spread at a faster rate than the European strain, which is established in North America. Eradication projects for the Asian strain were conducted in Oregon and Washington in 1992 and 1993, and in North Carolina in 1994 and 1995.

Isolated infestations of the European strain continue to be a problem outside the area where it is established. They usually result from inadvertent movement of gypsy moth life stages from the generally infested area on articles such as cars, campers, outdoor funiture, and nursery stock. Between 1993 and 1995 there were nearly 200 eradication sites in 16 States (USDA APHIS 1994).

Port-of-entry activities to prevent all gypsy moth strains from entering the United States are ongoing (*app. B*). Detection surveys using pheromone traps continue nationally, to determine if the insect has been introduced and where eradication is necessary.

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Scientific notation

Scientific notation	Decimal equivalent	Verbal expression
1×10^{-10}	0.0000000001	One in ten billion
1×10^{-9}	0.000000001	One in one billion
1×10^{-8}	0.00000001	One in one hundred million
1×10^{-7}	0.0000001	One in ten million
1×10^{-6}	0.000001	One in one million
1×10^{-5}	0.00001	One in one hundred thousand
1×10^{-4}	0.0001	One in ten thousand
1×10^{-3}	0.001	One in one thousand
1×10^{-2}	0.01	One in one hundred
1×10^{-1}	0.1	One in ten
1×10^{0}	1	One
1×10^{1}	10	Ten
1×10^{2}	100	One hundred
1×10^{3}	1,000	One thousand
1×10^{4}	10,000	Ten thousand
1×10^{5}	100,000	One hundred thousand
1×10^{6}	1,000,000	One million
1×10^{7}	10,000,000	Ten million
1×10^{8}	100,000,000	One hundred million
1×10^{9}	1,000,000,000	One billion
1×10^{10}	10,000,000,000	Ten billion
1×10^{11}	100,000,000,000	One hundred billion
1×10^{12}	1,000,000,000,000	One trillion

Unit Conversions and Abbreviations

To convert . . .	Into . . .	Multiply by . . .
acres	hectares (ha)	0.4047
gallons (gal)	liters (L)	3.785
gallons per acre (gal/acre)	liters per hectare (L/ha)	9.34
grams (g)	ounces (oz)	0.035
hectares (ha)	acres	2.471
inches (in)	millimeters (mm)	25.4
kilograms (kg)	pounds (lb)	2.2046
kilograms per hectare (kg/ha)	pounds per acre (lb/acre)	0.892
kilometers (km)	miles (mi)	0.621
liters (L)	gallons (gal)	0.264
miles (mi)	kilometers (km)	1.609
milligrams (mg)	ounces (oz)	0.000035
millimeters (mm)	inches (in)	0.03937
ounces (oz)	grams (g)	28.35
ounces per acre (oz/acre)	grams per hectare (g/ha)	70.1
ounces per acre (oz/acre)	kilograms per hectare (kg/ha)	0.0701
pounds (lb)	grams (g)	453.6
pounds (lb)	kilograms (kg)	0.4536
pounds per acre (lb/acre)	kilograms per hectare (kg/ha)	1.121
pounds per gallon (lb/gal)	grams per liter (g/L)	119.8
square centimeters (cm^2)	square inches (in^2)	0.155

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Do not apply insecticides when there is danger of drift or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of insecticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If hands become contaminated with an insecticide, do not eat or drink until you have washed. In case an insecticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label and get prompt medical attention. If an insecticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Store insecticides in original containers out of the reach of children and animals, and away from food and feed.

Dispose of surplus insecticides and empty containers promptly, using recommended practices.

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